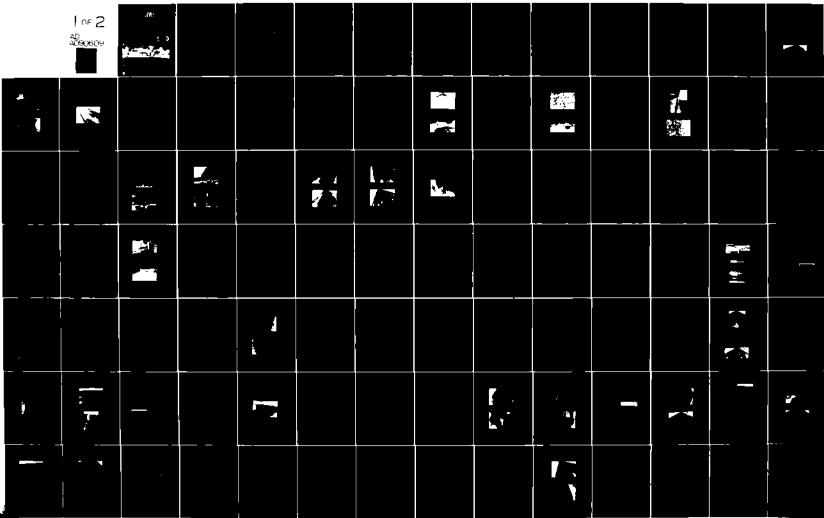
AD-A090 609 DARTER AND BARENBERG CONSULTING ENGINEERS URBANA IL F/G 13/2
BONDED CONCRETE OVERLAYS: CONSTRUCTION AND PERFORMANCE.(U)
SEP 80 M I DARTER, E J BARENBERG DACA39-79-M-0124
UNCLASSIFIED WES/MP/GL-80-11 NL

1 OF 2
AD
A090609



AD A090609

(2) LEVEL II

SC

MISCELLANEOUS PAPER GL-80-11

BONDED CONCRETE OVERLAYS: CONSTRUCTION AND PERFORMANCE

by

Michael I. Darter, Ernest J. Barenberg

Darter and Barenberg, Consulting Engineers — New
100 W. George Huff
Urbana, Ill. 61801

DTIC
ELECTE
OCT 2 1 1980
S D
B

September 1980

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314
(Project No. 4K07812AQ61)

Under Purchase Order DACA39-79-M-0124

Monitored by Geotechnical Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

New
411 987

80 10 6 143

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER Miscellaneous Paper GL-80-11 (19)	2. GOVT ACCESSION NO. AD-A090 609 (18)	3. RECIPIENT'S CATALOG NUMBER WES/MP/-
4. TITLE (and Subtitle) BONDED CONCRETE OVERLAYS: CONSTRUCTION AND PERFORMANCE. (9)		5. TYPE OF REPORT & PERIOD COVERED Final report,
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) (10) Michael I./Darter Ernest J./Barenberg		8. CONTRACT OR GRANT NUMBER(s) Purchase Order DACA39-79-M-0124
9. PERFORMING ORGANIZATION NAME AND ADDRESS Darter and Barenberg, Consulting Engineers 100 W. George Huff Urbana, Ill. 61801		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Project No. 4K07812AQ61
11. CONTROLLING OFFICE NAME AND ADDRESS Office, Chief of Engineers, U. S. Army Washington, D. C. 20314 (11)		12. REPORT DATE Sep[redacted]980 (12)
		13. NUMBER OF PAGES 126
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) U. S. Army Engineer Waterways Experiment Station Geotechnical Laboratory P.O.Box 631, Vicksburg, Miss. 39180		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Concretes	Pavements
Curing	Performance
Grouts	Reflective cracking
Joints (Junctions)	Reinforced concrete
Overlays (Pavements)	

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

—>Several bonded concrete overlays have recently been placed on street, highway, and airfield pavements using new equipment and techniques. This report summarizes the current state of the art and industry experience as well as reviewing procedures and performance of older bonded overlays. A review and summary of (a) surface preparation of the existing slab, (b) joint and crack treatment, (c) bonding methods, (d) concrete overlay mixtures, (e) curing

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

411 7??

20. ABSTRACT (Continued):

methods, (f) jointing techniques, (g) performance of recent overlays to date, and (h) the use of reinforcement in bonded overlays are included. Also, a list of important conclusions and research needs is provided.

PREFACE

This report was prepared for the Office, Chief of Engineers, U. S. Army, under FY 79 authority for O&MA Facilities Investigation and Studies Program dated 1 May 1979, Project 4K07812AQ61.

This investigation was conducted and the report prepared by Drs. Michael I. Darter and Ernest J. Barenberg, Consulting Engineers, Urbana, Illinois, for the U. S. Army Engineer Waterways Experiment Station (WES) under Purchase Order DACA39-79-M-0124. Mr. Carlton L. Rone, WES Geotechnical Laboratory, was project monitor. The authors express their thanks to Mr. Rone for his contributions to the study. Appreciation is also expressed to the following individuals for their assistance in various field trips and interviews: Mr. M. J. Knutson of the Iowa Concrete Paving Association, Mr. J. V. Bergren of the Iowa Department of Transportation, Mr. Harlan Hedeman of the Clayton Co. Engineers Office, and Mr. Wouter Gulden of the Georgia Department of Transportation. Thanks also goes to Messrs. Mark Snyder and David Morrill for assistance in the review of literature, and to Ms. Ruth Pembroke for typing the manuscript.

Directors of WES during the investigation and the preparation of the report were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. Fred R. Brown.

CONTENTS

CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) UNITS OF MEASUREMENT

U. S. customary units of measurement used in this report may be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
gallons per minute	3.785412	cubic decimetres per minute
gallons per square yard	4.5273	cubic decimetres per square metre
inches	2.54	centimetres
miles (U. S. statute)	1.609344	kilometres
mils	0.0254	millimetres
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic yard	0.5932764	kilograms per cubic metre
bags (94 lb)("sacks") per cubic yard	55.768	kilograms per cubic metre

BONDED CONCRETE OVERLAYS: CONSTRUCTION AND PERFORMANCE

1.0 INTRODUCTION

This report summarizes the industry experience and current state of the art of bonded concrete pavement overlays. Within the past few years the interest in bonded concrete overlays for streets, highways, and airfields has greatly increased. Several new bonded overlays have been constructed using new milling equipment and various new techniques, and additional overlays are being planned. With the large number of concrete pavements needing rehabilitation and/or strengthening it is important that a cost-effective, reliable method of providing bonded concrete overlays be developed. Thus, there is a need to summarize available new information and to compare it with previous results.

Bonded concrete overlays have been placed on existing concrete slabs since the early 1900's. Many of these projects have been documented in the literature listed in the bibliography in this report. The performance of bonded overlays has generally been good, provided sufficient bond between the overlay and the existing slab was developed, and various other design considerations are adequately provided for. A number of bonded overlay projects have recently been constructed in Iowa, Illinois, Minnesota, New York and elsewhere using a variety of techniques. To prepare this report, the authors reviewed literature from many sources, surveyed several projects in Iowa and Georgia, and interviewed personnel involved in the projects. They also assisted with the design and construction of the

Willard Airport bonded overlay in Illinois. Although many aspects of bonded concrete technology are well understood and reliable bonded overlays can be obtained, there still remain several unresolved problems with areas of potential improvemrnt in the technology and in cost reductions that need additional research.

This report provides a review and summary of surface preparation of the existing slab, joint and crack treatment, bonding methods, concrete overlay mixtures, curing methods, jointing techniques, performance of overlays to date, and the use of reinforcement in the bonded overlays. A list of important conclusions and research needs is also provided.

2.0 EXISTING SURFACE PREPARATION

Surface preparation consists of any work that must be accomplished to achieve adequate bond of the new overlay. The treatment of joints and cracks is presented in Section 3.0. It is desirable to minimize the surface preparation effort required to achieve a reliable bond to keep construction costs as low as possible. Existing surfaces may exhibit a variety of conditions including scaling, map cracking, contamination by oil and other materials, excessive popouts, spalling from "D" cracking or reactive aggregate, and localized breakup areas. The specific condition of the surface must be carefully considered in specifying the needed surface preparation to assure adequate bond.

2.1 Repair of Existing Slab (excluding joints and cracks)

Performance of bonded concrete overlays on pavements in service has demonstrated the need for repairing any areas of localized breakup. If not patched, these areas will quickly reflect through thin overlays (e.g. < 4 in.).* Thicker overlays may delay the breakup for several years, but all cracks in non-reinforced slabs will eventually reflect through, especially under heavy traffic. Figures 2.1 through 2.5 illustrate some reflective cracking through thin-bonded overlays. The base slab was non-reinforced.

2.2 Surface Treatment

Since bonding of the new overlay with the existing slab is essential, the crucial question is what bond strength is needed to provide a reliable permanent bond? Then, what amount of surface preparation is necessary to achieve this bond strength over the entire slab area? Bond strength has commonly been measured by direct shear across a core or prism specimen (22).

---

* A table of factors for converting U. S. customary units to metric (SI) units of measurement is found on page 4.

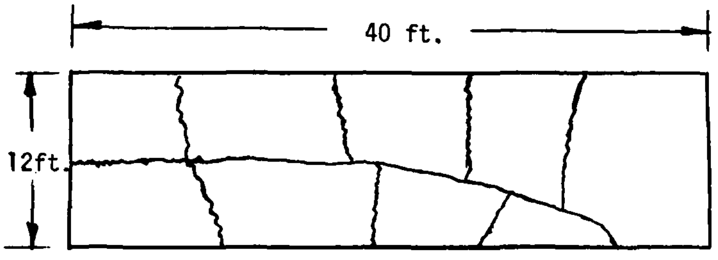


Figure 2.1. Diagram of Cracking Existing in Slab Before 4-in. Bonded Overlay was Placed in Clayton, Co., Iowa in 1977.

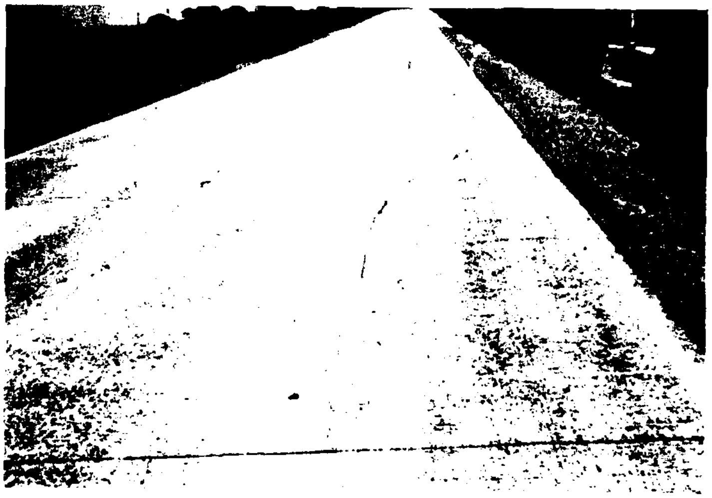


Figure 2.2. Reflective Cracking in 1979 on Slab Shown in Figure 2.1, View 1.

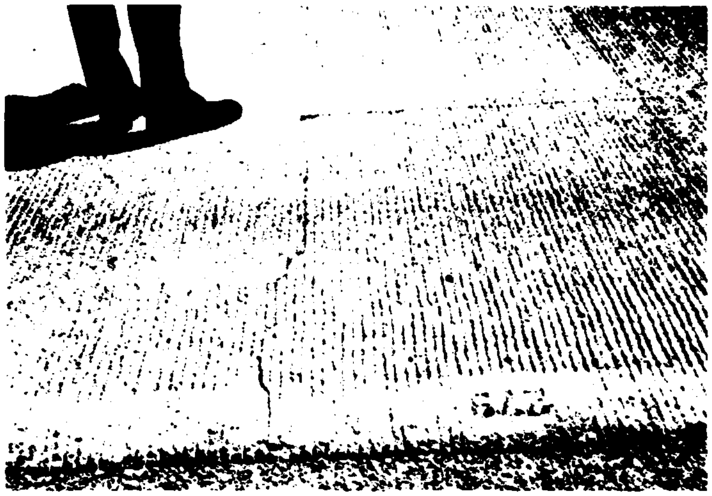


Figure 2.3. Reflective Cracking in 1979 on Slab Shown in Figure 2.1, View 2.

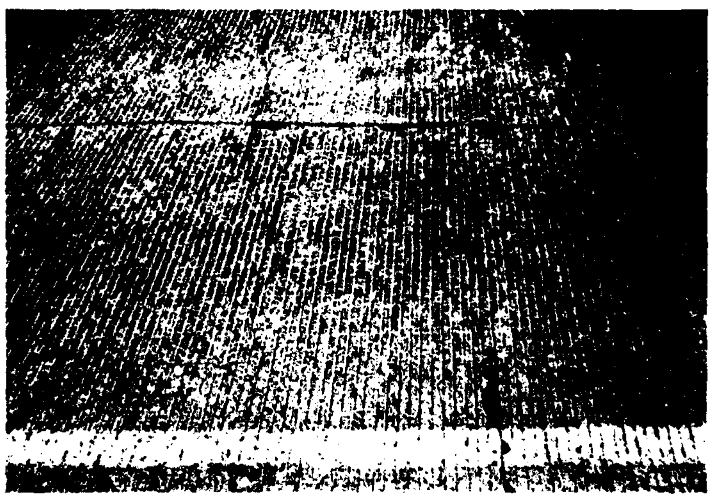


Figure 2.4. Reflective Cracking in 1979 on Slab Shown in Figure 2.1, View 3.

Figure 2.5. Reflective Cracking in 1979 on Slab Shown in Figure 2.1, View 4.

The direct shear strength of existing concrete slabs measured on cores from the pavements ranges from 700 to 1700 psi (1,2,7,22). Extensive coring of in-service projects and other observations of structural beams led Felt to conclude that bond strengths of 200 psi, or even less, may be adequate (7). Perhaps even more important than a high mean bond strength may be that areas of low or no bond must be eliminated.

Extensive laboratory and field tests on the bonding of concrete overlays were conducted by Felt at the Portland Cement Association (PCA) in the 1950's. He concluded that: "The most important single factor that influences bond is the surface condition of the old concrete. The surface must be clean and the concrete must be sound. A slight degree of roughness is desirable, but extremely rough surfaces are not required" (7).

A variety of surface preparations have been used over the years, including the following (sometimes in combination): sweeping, washing with water and brushes, mechanical scarification of 1/4 to 1 in. of surface, sandblasting, water blasting, and treatment with hydrochloric acid (HCl). These have been used in combination with various bonding agents that are discussed under "Bonding Methods." Typical practice before the 1950's was as follows:

> "If a bond is desired between the new concrete surface and the old concrete base, the old concrete should be scrubbed clean with water and brooms. Just before the new concrete is deposited the old surface is covered with a wash coat of neat cement and water"(42).

Some projects, however, were scarified with mechanical equipment in addition to the cleaning.

The mean bond strength of cores cut in 1953 from 11 overlay projects having a mean age of 10 years are as follows (8):

Surface Preparation	Mean Bond Strength, psi
1. Surface broom cleaned and/or blown clean with compressed air, bonding grout or cement applied to wet surface	263 psi (36% cores < 200 psi)
2. Surface scarified or other surface removal, then broom cleaned and/or blown clean with compressed air, bonding grout or cement applied to wet surface.	376 psi (17% cores < 200 psi)

Cores were obtained in 1964 by Gillette (8) of PCA from six projects overlayed from 1954 through 1963 (mean age 5 years) that were all scarified or removed by another surface removal method, dampened, and acid etched. Details of the process are given by Westall (9,10). The mean bond strength from the cores was 435 psi (range 224-750 psi). None of the cores had a bond strength less than 200 psi.

The laboratory tests conducted by Felt on methods of cleaning and preparing an old base concrete slab showed that cleaning and etching of the surface with HCl resulted in bond strengths in the 300-500 psi range, sandblasting the old surface resulted in bond strengths of 48 to 102 psi, scarifying the surface resulted in a mean bond strength of 407 psi, and a thoroughly brushed and water washed surface provided only 21 psi. A summary of the effect of surface preparation of the existing concrete on bond strength is given in Table 2.1.

These field and lab results together indicate that some roughening by mechanical means and cleaning the surface with HCl increase the bond strength between the overlay and existing slab.

The specific recommended procedure based upon work at PCA in the 1950's was as follows:

Table 2.1. EFFECT OF SURFACE PREPARATION OF OLD CONCRETE ON BOND[a] (7).

	Bond Strength (psi)	
	1:1 Grout	No Grout
HCl	301	228
HCl, internal vibration	363	212
Glacial acetic acid	52	68
Brushed and washed with water	21	4
Sandblasted, torpedo sand, shotcrete gun	102	88
Sandblasted, silica sand, commercial gun	48	64
Tennant machine, shallow waffle	283	326
Electric chisel, light chipping	163	162
HCl, 7 sk/cu yd concrete internally vibrated[c]	525	327
HCl, 11 sk/cu yd concrete internally vibrated	425	418
HCl, 7 sk/cu yd concrete[d]	358	-
Tennant machine, 7 sk/cu yd[d]	407	-

[a] Slabs, 16 by 40 in. sawed from 25-yr-old pavement, surfaced with 2-in. of 6-sk air-entrained concrete consolidated by surface vibration except as noted; data average of tests on four 8-in. prisms.

[b] Of old base slabs in air-dry condition.

[c] Base concrete for tests above this entry from different source and weaker than base concrete for remaining tests.

[d] Scaled but sound base.

NOTE: "sk/cu yd" denotes bags (94 lb) per cubic yard.

"To provide bond, the old surface must be cleaned and unsound material removed. When the old concrete is sound and durable, brooming and washing with water followed by hydrochloric acid has been found very effective for this purpose... Hydrochloric acid will not remove asphalt and tar which may be removed best with mechanical equipment or by sandblasting. Oil drippings are partially removed by the acid, but if they are extensive, they should be partially removed with a strong detergent before acid treatment.

If the old concrete surface is not sound and durable... This requires mechanical treatment with air hammers or other equipment. Cutting should continue until sound, durable concrete is exposed over the entire area... Final cleaning of an area where mechanical scarifying has been employed is an important construction step.

Compressed air followed by washing and brushing are used for this purpose. If possible, the area should be kept dry until all the dust has been blown off. If the dust becomes wet, it packs into hollows and crevices and can then be removed only by repeated washing and brushing followed by compressed air. Final cleaning with water under high pressure should be done sufficiently ahead of concrete placement to permit the surface to become practically dry" (7).

Since 1964 the Iowa Department of Transportation (DOT) has been using a method of bonding a concrete overlay on bridge decks. This method has been used successfully on over 100 bridges. The surface preparation (after areas of deterioration from steel corrosion are repaired) involves removing the surface to remove the top 1/4 in of concrete using a milling machine. This roughens the surface and removes oil, grease, and other surface impurities. Grout with a creamy consistency is thoroughly brushed onto the surface with hand brooms immediately in front of the concrete placement. Only a few minor localized failures have occurred on these bridge decks.

Based on the successful experience from the bridge deck overlay program, Iowa DOT adapted the method for bonding concrete pavement overlays. Recent projects constructed since 1976 have evaluated various methods of surface preparation among other aspects.

The first bonded concrete pavement overlay project by Iowa DOT was constructed on US 20 near Waterloo, Iowa in 1976. This project provides a comparison of three surface preparation methods. The surface was milled with a CMI Roto-Mill Pavement Profiler, which had a 9 ft 2-in.-width cutting head. This machine removed about 1/4 in. from the pavement surface and provided a face that was free from contamination of oil, tire rubber and paint strips. A photo of the Roto-Milled surface is given in Figure 2.6. Three passes were made--two outside passes were performed first, followed by a third pass for the remaining center portion of the 24-ft-wide slab. Details of the milling process and problems are given in Reference 1. Sandblasting was accomplished using a self-propelled, trailer-mounted sandblasting machine. After surface milling, or milling and sandblasting, or sandblasting only, and just prior to application of the grout, the entire surface was cleaned by airblasting. Mean bond strengths obtained using this surface preparation were very high and reported as follows (1) (NOTE - the concrete mixture used is described in Section 5):

	Mean Bond Strength, psi
Milling and Sandblasting	955
Milling only	816
Sandblasting Only	1012
Existing Slab Shear Strength	1186
New Concrete Overlay Shear Strength	1266

A second project using a bonded concrete overlay was constructed in Clayton Co., Iowa in 1977 (2). Sandblasting, water blasting, and surface milling were all evaluated on this project. Surface milling was performed using a Gallion RP-30 Road Planer which has a 30-in.-wide cutting head. The upper 1/4 inch of surface was removed and then airblasted to remove the debris. Sandblasting was accomplished using a trailer-mounted

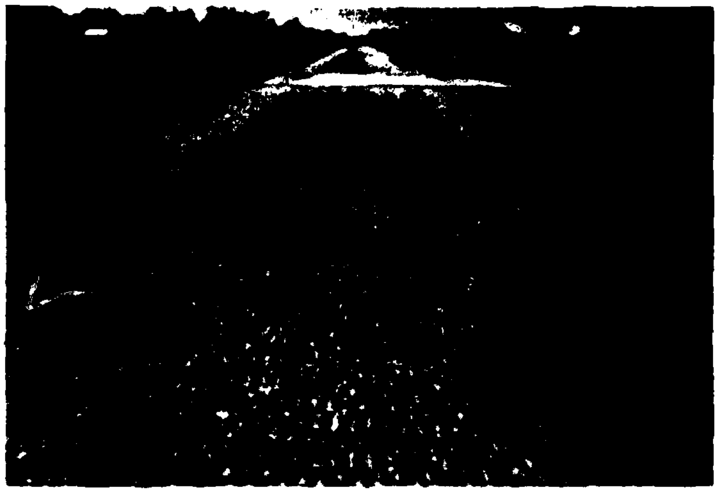


Figure 2.6. CMI Roto-Milled Surface of Slab on Waterloo, Iowa Project in 1977.

Figure 2.7. CMI Roto-Mill Used at Willard Airport, Champaign, Illinois in 1978.

blasting unit at a nozzle pressure of 110 psi and a coverage rate of 10 square yards per minute. The sandblasting also proved capable of adequately cleaning the unmilled surface and removing paint strips. The major problem was excess dust. Water blasting was accomplished using trailer-mounted equipment that delivered 100 gallons of water per minute at a pressure of 6000 psi through 30 stainless steel pan nozzles of 0.04-in. diameter. Water blasting adequately cleaned the surface but did not satisfactorily remove paint strips. It was concluded that if this equipment were to be used on future projects, it would require redesign to produce greater pressures or possibly with sand injected and blasted along with the water.

Shear bond strengths developed with the various methods of surface preparation as determined from cores after construction are as follows (note that a grout of equal parts by weight of cement and sand mixed with sufficient water to form a stiff slurry was used as a bonding agent applied to a dry surface):

	Mean Bond Strength, psi
Waterblast + grout	559
Sandblast + grout	592
Surface Milling + grout	420*

The bond shear of the old slab was 811 psi and that of the new overlay concrete 893 psi.

A bonded concrete overlay constructed in 1978 at Willard Airport, Champaign, Illinois employed a CMI Roto-Mill shown in Figure 2.7 to mill the existing surface to a depth of approximately 1/2 inch (21,22). A potential problem developed from milling across the transverse joints which caused deep spalling of the joint as shown in Figure 2.8. It is

* Lower value may be due to slight fractures by the carbide-tipped teeth of the milling machine. Sandblasting removes the fractures.

Figure 2.8. Roto-Milled Transverse Joint at Willard Airport.

Figure 2.9. Brooming of Roto-Milled Surface (Foreground) and Water Blast Cleaning of Surface (in Background) at Willard Airport.

not known how this spalling will affect pavement performance, if at all. Such spalling can reportedly be prevented by placing a grout material in the joint before milling, and removing by sawing after milling, but the procedure is quite expensive and the benefits uncertain. After milling, the surface was cleaned by brooming and water blasting as shown in Figures 2.9 and 2.10. Water pressure up to 5000 psi was used in this operation. This procedure resulted in a clean, rough surface as shown in Figure 2.11. The brooming and water blasting removed all dust and debris from the milled surface. Some loose materials, however, remained in the joints. The surface was blown free of dust and/or water with compressed air (manually with a hand-held hose) just before a grout was broomed onto the surface. The surface was required to be dry before the grout was placed, although a few times grout was placed when the surface was damp after a rain. The mean bond strength as measured in shear on cores cut approximately 1 month after construction was 641 psi. The shear strength of the existing concrete slab was 1709 psi, and the overlay slab was 1183 psi (22).

Another recent bonded concrete overlay was placed in 1978 in Minnesota using the general Iowa method (44). The bonded 2- to 3-in. non-reinforced concrete overlay was placed on a section of badly spalled continuously reinforced concrete pavement (CRCP) Interstate highway. The overlay is performing well after 1 year, and less than 50 percent of the transverse cracks in the original CRCP have reflected through the bonded overlay.

2.3 Areas of Potential Research Needs

The major unresolved problems for surface preparation of bonded overlays concern the need for mechanical milling. The early project field

Figure 2.10. Water Blast Cleaning of Roto-Milled Surface at Willard Airport.

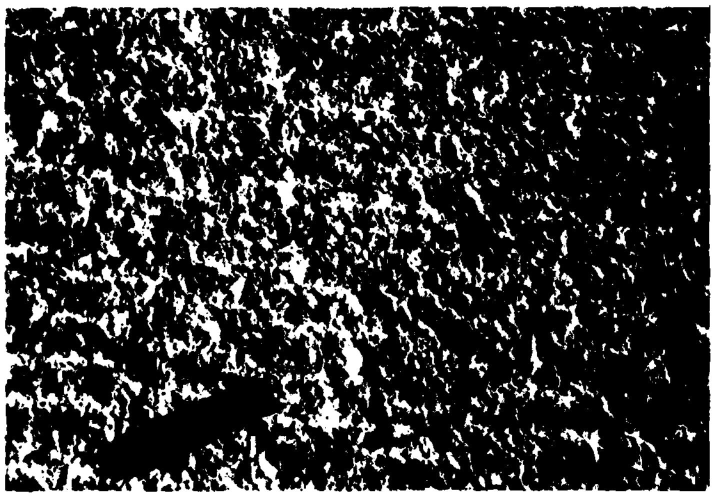


Figure 2.11. Cleaned Roto-Milled Surface Ready to Receive Grout at Willard Airport.

core tests showed a definite advantage of milling and cleaning over water cleaning only, which confirms the PCA laboratory tests. However, tests by Iowa on two projects showed high bond strengths with various methods of surface preparation: surface milling, milling and sandblasting, sandblasting and water blasting. Paint stripes cannot be removed by water blasting alone. These methods need further study to determine their reliability.

3.0 TREATMENT OF JOINTS AND CRACKS PRIOR TO OVERLAY

The success of a bonded concrete overlay also depends upon the proper treatment of joints and cracks prior to the placement of the overlay. Based on the results from many projects reported in the literature and the survey of several projects by the authors, it is concluded that practically all discontinuities in the base slab (e.g., joints, cracks) will reflect through the concrete overlay within a few years. Thus, all studies recommend that joints in the overlay be placed directly over joints in the base slab, and all cracked or broken slabs be replaced before overlaying.

The real problem is to determine what condition of the joint or crack (or what level of deterioration) warrants what level of repair. This is a particularly difficult problem when "D" cracking or reactive aggregate distress exists. Other variables must also be considered in making these decisions, including the level of traffic and thickness of the overlay.

3.1 Joint Treatment

The problem is in deciding at what degree of deterioration a joint should be patched full-depth, partial-depth, or not patched at all. The removal of concrete at a few joints in various stages of deterioration and careful examination of joint conditions should provide an insight into the deterioration of the underlying concrete for various conditions observed at the surface. It is believed that whatever cracking condition is observed in the existing slab will reflect through a thin bonded overlay (i.e., $<$ 4 in.). Thus if the condition of the joint in the existing slab is becoming unacceptable, some type of repair should be accomplished prior to placing the overlay.

For the U.S. 20 project near Waterloo, Iowa, both partial- and full-depth patches were utilized to repair spalled transverse joints (caused by "D" cracking) (1). Full-depth patches were placed on a few badly deteriorated joints. Most of the joints on the project had not seriously deteriorated, but it was felt that they would in the near future. In light of this, it was decided that partial-depth removal of the concrete near the joint and patching with the resurfacing concrete would be used rather than full-depth removal and replacement. Based on visual evaluation of the surface, many joints on this project were only slightly distressed, which raised the question of how they should be prepared. It was decided to grind off only the top 1/4" of concrete at 30 percent of the deteriorated transverse joints and approximately 3-4 inches of concrete from the remaining joints. It was noted that some difficulty was experienced in attaining satisfactory partial-depth removal to the 3- to 4-inch depth. This was due in part to impatience of the milling machine operator, and in part to the shields on the CMI Roto-Mill machine which limited the cutting depth to two inches. It was felt that the Roto-Mill could have been used successfully to accomplish the partial-depth removal, but that a twelve-foot wide grinding capability would have been desirable. A smaller Gallion Road Planer was successfully used to widen the area of removal at the intersection of joints.

In the Spring of 1977 (about 1/2 year after construction), bonding in these areas was checked with a mechanical delamination detection device (Delamtect). With the exception of one small area, there was no indication of delamination and it was determined that complete bonding had been achieved. Photographs of typical base slab pavement distress prior to

overlay are shown in Figures 3.1 and 3.2. A photograph of the overlay where, after 3 years, spalling from "D" cracking has reflected through is shown in Figure 3.3. The localized area with "D" cracking has become debonded. Thus the original slab "D" cracking has apparently continued as illustrated in a photo of a joint in a non-overlayer portion of the project in Figure 3.4. Areas of the project that were not overlayed have increased considerably in "D" cracking severity.

The placement of partial-depth patches at joints exhibiting "D" cracking may be questionable, depending on the condition of the underlying concrete. Several partial-depth patches of 3-in. depth were placed in Illinois to repair surface spalling in "D" cracked pavements. These patches have lasted about 1-2 years before breaking up under heavy traffic (46). Of course, the placement of a bonded overlay would provide a greater structural thickness, but if the concrete under the partial-depth patch is deteriorated, this area will probably fail long before other areas of the slab.

The bonded overlay project in Clayton County, Iowa placed in 1977 contained spalling at several joints (no "D" cracking reported on this project). The repair procedure included partial-depth repair of 27 joints, full-width repair of 13 joints, and one-half pavement-width repair at 14 joints. Depths of partial-depth repair varied with the amount of deterioration, but averaged 3 inches. The Gallion RP-30 Road Planer was used to mill the concrete from along the joint in a semicircular fashion. After the concrete removal, the patch area was cleaned by water blasting and airblasting, and then grouted with a 1:1 sand-cement grout prior to overlay. A survey conducted 2 years after construction showed no significant joint deterioration (except for secondary cracking along the joint as discussed in Section 7).

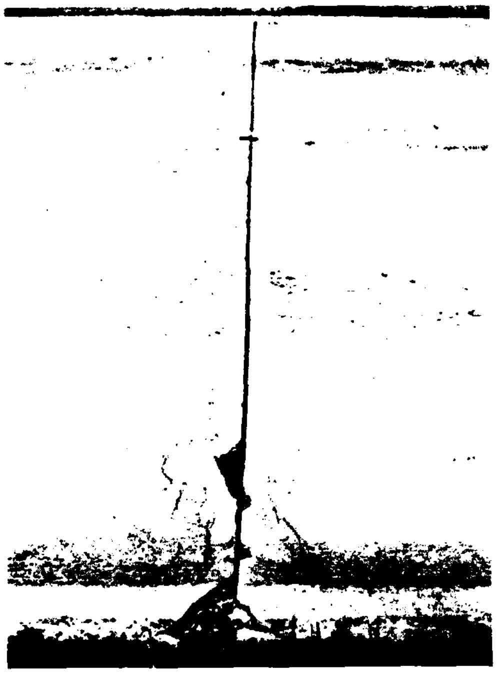


Figure 3.1. Typical Joint Showing "D" Cracking Before Overlay Was Placed at Waterloo, Iowa (Some Joints Were Worse Than This and Were Patched) 1977.

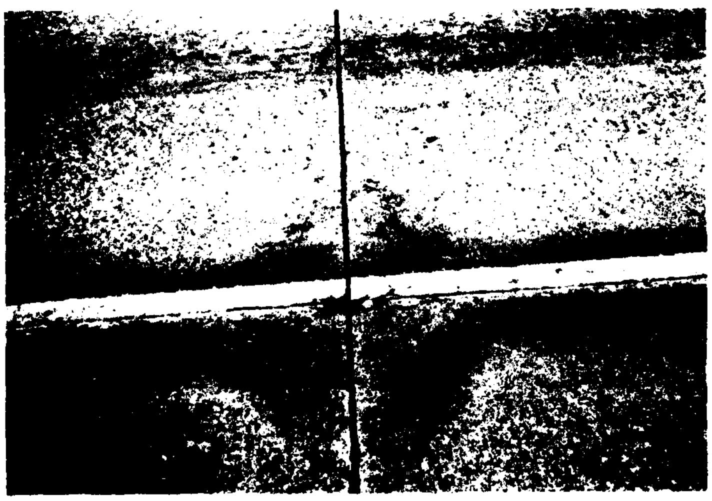


Figure 3.2. Typical Joint Showing "D" Cracking Before Overlay Was Placed at Waterloo, Iowa.

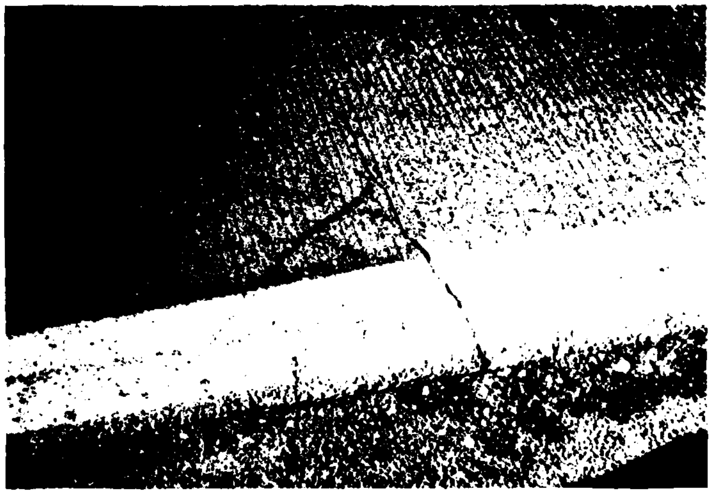


Figure 3.3. Localized Area of Debonding and Reflective Cracking of "D" Cracked Base Slab at Waterloo, Iowa, 1979.

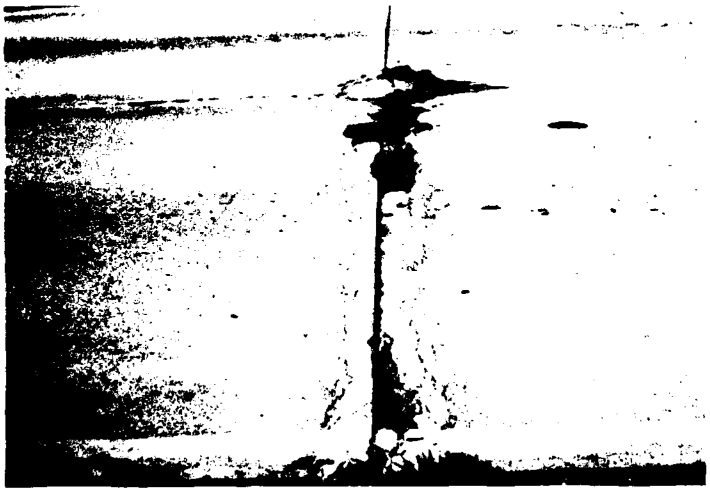


Figure 3.4. Progression of "D" Crack Deterioration in Original Slab in Waterloo, Iowa, 1979.

The joints in the existing slab at Willard Airport, Champaign, Illinois showed very little spalling. However, the CMI Roto-Milling produced some deep spalling in both transverse and longitudinal joints as was illustrated in Figure 2.8. The spalled joints were cleaned by power sweeping and high pressure water blasting and this usually left a sizable depression along the joint. These areas were filled with grout and concrete during the overlay operation. After one year no noticeable distress has occurred at the joints.

3.2 Treatment of Cracks

Cracks can be classified into the following categories: (1) hairline, (2) working with some spalling, and possibly some faulting, and (3) working with severe spalling and possibly serious faulting. No mention is made of any particular treatment of cracks in reports on bonded concrete overlays. Typically, nearly all cracks in the base slab have reflected through the bonded overlays within a few years. The reflected cracks are illustrated in Figures 3.5 through 3.9. The degree of treatment of cracks in the base slab depends in part on the level of traffic and the thickness of the overlay. For low volume roads, it would appear to be cost-effective to patch even spalled working cracks in the base slab. However, for heavily trafficked pavements, the repair of all working cracks appears to be necessary. Repair of the cracks can be accomplished by full-depth patching with tie bars set into the slab on both sides of the patch to provide permanently tight joints between the existing slab and the patch. In this case there is no need to provide joints in the overlay above the tied joints in the repair patch since these are not working joints.

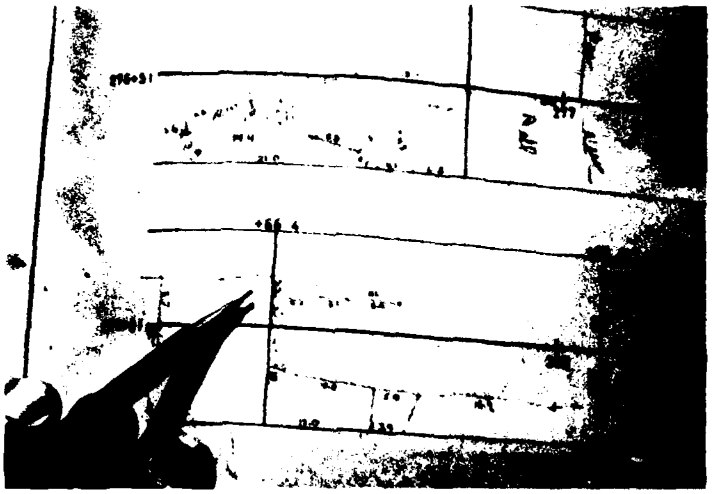


Figure 3.5. Diagram of Cracking in Base Slab at Clayton Co., Iowa, 1977.

Figure 3.6. Photo of Reflection Cracking in Concrete Overlay for Slab Shown in Figure 3.5, 1979.

Figure 3.7. Diagram of Cracking in Base Slab at Clayton Co., Iowa, 1977.

Figure 3.8. Photo of Reflective Cracking in Concrete Overlay for Slab Shown in Figure 3.7.

Figure 3.9. Closeup of Cracking in Figure 3.8.

Another possibility for treatment of cracks where the bonded overlay is relatively thick (e.g., > 4 in.), is to place tie bars across the crack in the overlay. When the crack does reflect through the overlay, it will be held tightly closed. This procedure was used on the Willard Airport overlay for all cracks in existing slabs that were not removed and replaced. Slabs at Willard Airport were 20 x 12.5 ft in size of non-reinforced concrete. Any slab divided into 3 or more pieces was partially or completely removed and replaced. Where only a portion of the slab was replaced, tie bars were placed across the joint (between the original slab and the new patch). After one year of service none of these cracks has reflected through, but the overlay was fairly thick (8 in.) and it may take a few years for these cracks to reflect through.

A bonded plain concrete overlay was placed on I-35W North of St. Paul, Minnesota in 1978 (44). The base pavement was a continuously reinforced concrete pavement (CRCP) with some bad spalling caused by corrosion of the reinforcement. The CRCP contained the typical series of tight transverse cracks randomly spaced from about 1 to 10 feet, held together by the steel reinforcement in the slab. The surface was milled 1/4 to 1 in and a grout was broomed onto the surface. It was concluded that deep milling of over 1/4 in would result in extension of existing delaminations. Concrete milling at 1/2-in. increments was found to be more cost-effective than a single pass milling to depths of 1 to 2 inches.

Concrete overlays were then placed of 2- and 3-in. thickness. A few cracks reflected through the overlay soon after completion, and after one year a majority of the cracks have reflected through, although

cracks are very tight. When the base slab has cracks that are tight and reinforced, there are no data to indicate the reflected crack will spall or open up.

Four partially bonded concrete overlays were constructed on 200 feet of Columbus Avenue, in Anderson, Indiana in 1976. One test section utilized strips of impregnated roofing felt which were positioned over all cracks in the old pavement. Small quantities of fresh concrete were used to hold these strips in place while the concrete was placed. Performance data on the section were not given (13).

The use of a reinforced overlay to control cracking is discussed in Section 9.

3.3 Areas of Potential Research Needs

There is still much uncertainty as to the specific effect that joints and cracks in various states of deterioration have upon the performance of bonded overlays. The effects will vary depending on traffic level, overlay thickness, and other variables. Additional research is needed to develop decision criteria relative to the needed level of repair of joints and cracks prior to overlay. Some additional research is also needed in identifying the most cost-effective ways to make such repairs. The performance of overlays in Iowa and Illinois should be carefully followed to evaluate the effectiveness of the methods used.

4.0 BONDING METHODS

Several methods have been used over the years to bond new concrete overlays to existing slabs. The various methods of surface preparation and joint and crack preparation are presented in Sections 2 and 3. This section concentrates on the moisture condition of the existing slab, the bonding materials used, and the placement of the bonding materials.

4.1 Moisture Condition of Existing Slab

The moisture condition of the surface of the existing slab can vary from dry to completely saturated. Research reported by PCA provides some basic information on the effect of the moisture on bond strengths. Concrete overlays were placed on laboratory cast base slabs that were either air-dry or damp. Data showed that better bond was generally developed with a dry surface for the base concrete than with a damp surface. Over a wide range of conditions a mean bond strength of 304 psi was obtained for the damp surface condition, while a mean of 432 psi was obtained for a dry surface condition. Figure 4.1 shows a plot of data from the studies of Felt (7). Regardless of the grouting condition, the dry surface condition resulted in a much higher bond strength (42% higher). However, it should be noted that even with the damp surface the bond strength was well above the suggested 200-psi minimum requirement.

The above results confirm some earlier studies by Withey (47), who found that concrete specimens that had dry-cured for three days developed better bond than specimens that had dried only one day. Waters (48) also found that the tensile strength of concrete across construction joints was higher when the old concrete was dry at the time the new concrete was placed.

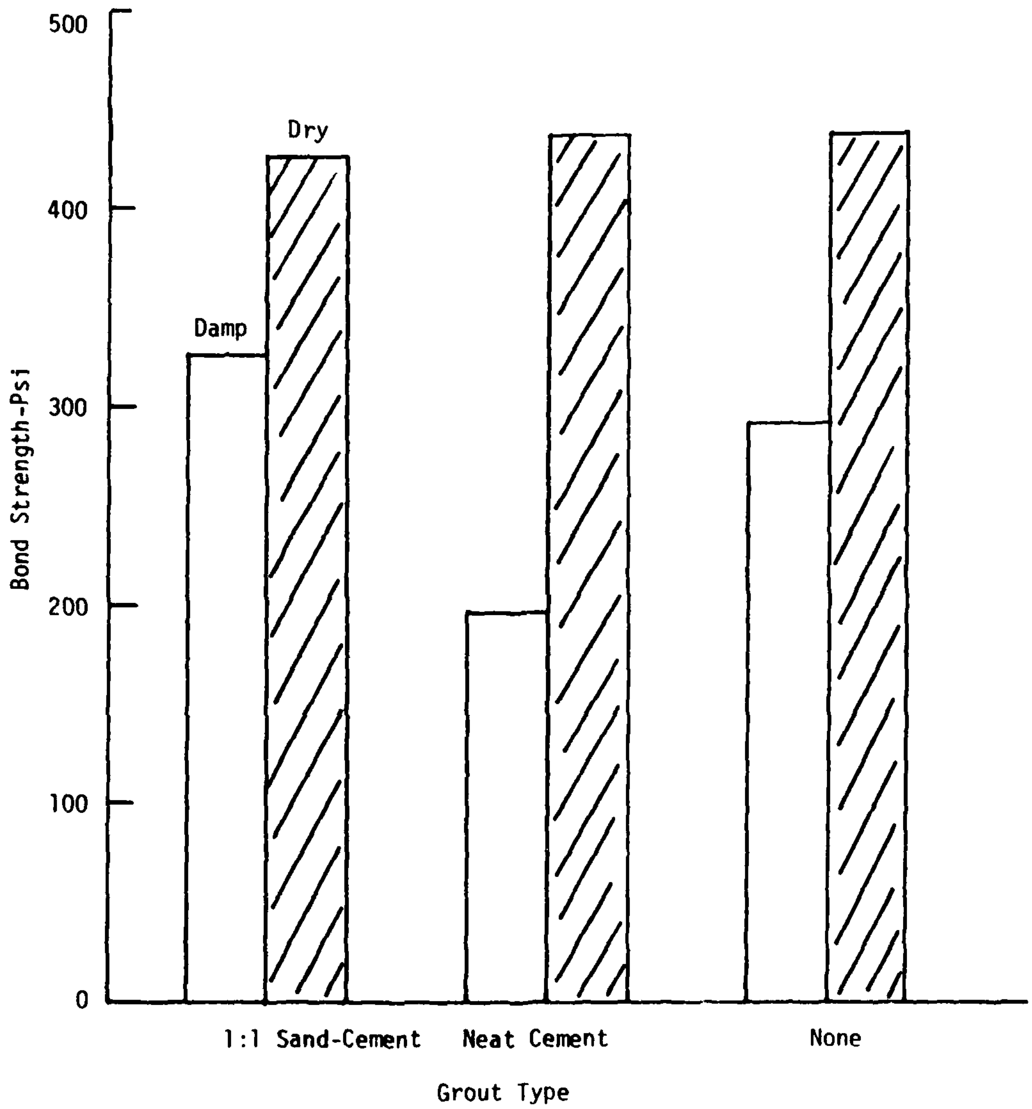


Figure 4.1. Effect of Dryness of Base Slab and Grouting on Bond Strength (Plotted from Data from Felt, 7).

Although lab studies at the PCA in the early 1950's indicated that a better bond is obtained on a dry surface, Gillette concluded that experience on larger projects has indicated that a damp (not wet) surface, free of standing water, gives better construction control. He concluded that this brings the temperature of the old surface closer to that of the plastic concrete, prevents rapid drying of the grout and prevents rapid hydration of the cement in the resurfacing (8).

M. J. Knutson of the Iowa Concrete Paving Association, however, concludes that the excellent bonds obtained in Iowa are due to a dry surface, and that a wet surface will cause bonding problems.*

---

* Personal communication, M. J. Knutson, Iowa Concrete Paving Association, Des Moines, Iowa, 8 October 1979.

4.2 Bonding Materials

The major types of bonding materials used for bonded overlays include (1) sand-cement grout and (2) neat cement. Other applications tried in the laboratory include cement dust applied to both wet and dry slab surfaces, a grout sprayed onto the surface, and various types of epoxy and other bonding compounds such as latex.

Results from the PCA study as plotted in Figure 4.1 for laboratory cast slabs indicate that the differences in bond strength between a 1:1 sand-cement grout, neat cement, and no grout were insignificant. However, Felt concludes:

> "The data ... show also that grout frequently increases bond... when grout was not used, only 2 tests in 23 showed superior bond (over 400 psi); whereas when grout was used 21 treatments out of 47 showed superior bond. The data indicate little difference between a sand-cement grout, a neat cement grout, a retempered grout, a grout containing $CaCl_2$, or a grout formed by spreading dry cement on a damp surface" (7).

Felt also concludes that grouts may be brushed on or sprayed on pneumatically, mixed for a considerable time before applying, and spread for some time before the concrete overlay is placed, but not so far in advance that excessive drying of the grout occurs.

Results obtained from tests on a 28-year-old base slab showed that grout had a substantial effect in increasing bond. The mean bond strength from the grouted (1:1 sand-cement) slabs was 234 psi, whereas the mean bond strength from non-grouted slabs was 186 psi (or a 26% increase) (7). Felt also reports on an experimental two-inch bonded concrete overlay placed on a 21-year-old concrete street in Wauwatosa, Wisconsin in 1951. Mean bond strengths after one year from areas where a 1:1 sand-cement grout was used was 275 psi; whereas the bond strength from non-grouted areas was only 197 psi. A 28 percent increase in bond strength occurred with the grout.

Some recent projects constructed in Iowa provide some additional information on the effect of bonding materials. The U.S. 20 projec+ near Waterloo constructed in 1976 used a 1:1 sand-cement grout combined with enough water to obtain a creamy consistency. Mean bond strengths of 1074 psi were obtained (range 297-1570 psi).

The bonded concrete project in Clayton County in 1977 also used a 1:1 sand-cement grout (2). The first several loads of grout used on this project were mixed and hauled in transit mix trucks. The time of retention of the grout on the trucks before total unloading varied from 2 hr., 10 min. to 5 hr., 25 min. This delay was due in part to breakdowns in the paving operations. Later tests showed a decrease in bond strength in areas where the grout used had been on the truck for longer than 3 hours. Due to the long haul time and the possibility of delays in the paving operation, the contractor found he could only haul and apply one cubic yard of grout within the specification time of 90 minutes. In view of this, he decided to mix the grout in his central mix plant in two cubic yard batches and transport it to the paving site in agitator trucks. There was no visible difference between the ready-mixed grout and grout mixed in the central plant and hauled to the paving site in agitators. No difference in bond strengths was checked and both methods appeared satisfactory. In the last 475 feet of the project, a neat cement-water grout consisting of 1376 lbs of cement mixed with 853 lbs of water was used. This was tried to test the bonding capabilities of such a mix in the event that a spray application might be developed. Grout was spread by six laborers wielding brooms and squeegees. Brooming seemed to spread the grout satisfactorily, but the squeegees tended to remove nearly all of the grout in areas prepared by sandblasting

or water blasting only. The area covered by the grout varied from 550 to 1050 square yards per cubic yard of grout, depending upon the type of surface preparation used. The average was about 750 square yards of coverage per cubic yard of grout applied. Bond strength tests indicated that the sand-cement grout averaged 654 psi while the cement-water grout averaged 600 psi. Both of these values were considered acceptable (2).

The Willard Airport, Champaign, Illinois overlay constructed in 1978 used a 1:1 sand-cement grout placed just ahead of the paving operation on a dry CMI Roto-milled surface. Enough water was used to give the grout the consistency of thick cream. Mixing was done in a central mix plant from which the grout was hauled in rotating drum trucks and dumped as needed. The grout was spread with stiff brooms and care was taken not to let the grouting operation get too far ahead of the paving crew. The mean bond strength one month after construction was 641 psi. A photo of the grout placement at Willard is shown in Figure 4.2. In outer areas of the runway where the concrete overlay was placed directly on the existing surface with no Roto-Milling, cleaning or grout, the bond strength was very low as all cores broke at the joint between the existing slab and the new overlay during curing. Figure 4.3 shows both the fully bonded slab (with grout already placed on the left), and the partially bonded (non-grouted) area on the right.

The use of other bonding materials has been studied. Several lab tests to determine average direct shear of different bonding materials were done using commercially available materials. The grout made from portland cement, sand, and water developed the highest average shear with 541 psi for 12 specimens. An epoxy bond developed 448 psi averaged for 12 specimens and latex-modified concrete with no bonding agent developed an

Figure 4.2. Spreading of Sand-Cement Grout on Roto-Milled Surface of Willard Airport, Champaign, Illinois, 1979.

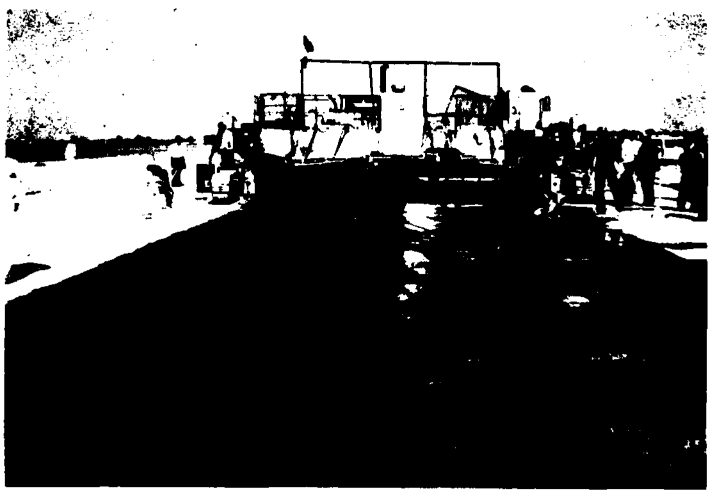


Figure 4.3. Photo Showing Milled and Grouted Fully Bonded Slab on Left, and Non-Milled and Non-Grouted Partially Bonded Area on Right at Willard Airport, Illinois, 1979.

average of 382 psi for three specimens. All bonding materials with the exception of two or three specimens of the latex-modified concretes withstood ASTM C-290 freeze-thaw tests (45).

Lab tests performed in 1960 using epoxy bonding agents were successful according to an article in Rural Roads in February of 1961. The results of these tests indicated that a 5- to 10-mil covering of epoxy resin will result in a strong bond of new concrete to old. This results in a coverage of about 120 square feet per gallon for a 10-mil film using a brushable compound. Epoxy resin must be applied to a surface free of dust, oil and moisture. A heavily worn or weathered pavement with exposed aggregate of at least 1/32" size is suitable for epoxy resin applications. It is essential that the surface be dry. Bonding of extruded curbing to concrete pavements and bonding of pothole patches have been done successfully using the epoxy adhesive as a bonding agent. In applications to large overlay areas it would be necessary to use a pumping unit capable of accurately pumping, metering and mixing appropriate quantities of base resin and catalyst in a mixing head near the spray nozzle as the mixed resin has a relatively short pot life (16).

One problem that exists in the normal placement of grout in front of the concrete paver occurs when the concrete trucks drive over it and track the grout over other areas of the pavement. This problem can be eliminated if a side dump concrete paver is used. Using side dump trucks is difficult, however, on roads with very limited working areas. Some types of mechanical means of placing the grout or neat cement must eventually be developed. The current method is very labor-intensive.

4.3 Areas of Potential Research Needs

Overall results from lab and field tests showed that bond strengths greater than 200 psi can be obtained without any bonding material, but the use of bonding agent generally significantly increases the bond strength. Results showed that a 1:1 sand-cement grout provides about the same bond as does a neat cement. This result is significant in that it is probably fairly easy to develop mechanized equipment to spread a neat cement, and thus reduce the cost of grouting. One set of data from grout sprayed at 26 psi showed a bond strength of 326 psi for a damp slab and 564 psi for a dry base slab (8). However, additional evidence is needed as to the true effectiveness of neat cement in a variety of situations.

Available field and laboratory evidence shows that a dry base slab provides a substantial increase in bond strength. However, since this may slow construction during rainy periods, some additional study may be needed to further examine the actual result of slightly damp base slab surfaces.

The development of mechanized equipment to place grout or neat cement is an important aspect in need of immediate attention.

5.0 CONCRETE MIXTURES FOR THIN-BONDED CONCRETE OVERLAYS

Thin-bonded overlays must conform to shrinkage and expansion of the support slab. Since the support slabs have generally reached an equilibrium condition with respect to short-term shrinkage and expansion, especially that due to moisture changes, it follows that the plastic shrinkage in the overlay should be held to a minimum to prevent plastic shrinkage cracking in the bonded overlay.

Thin-bonded concrete overlays are normally placed on existing concrete to either improve a surface condition, or to increase the structural section of a slab still in good condition. In some cases a thin-bonded concrete overlay might also be used on a pavement in which extensive joint repairs have been made, but in this application the overlay is intended primarily to give a uniform surface profile and appearance. In any case it would seem logical that the concrete used in the overlay should have a high resistance to deterioration under combined effects of climatic factors, including deicing agents where used and the action of traffic. Hence a high quality concrete would be appropriate for this use. Since the relative quantity of concrete used in this application is generally small compared with, say, a normal partially bonded or unbonded overlay, it seems that the added cost of additional cement or additives needed to produce a high quality concrete would be justifiable to achieve satisfactory performance of the overlay.

5.1 Mix Design for Concrete Used in Overlays

The concrete used in thin-bonded overlays to date has generally been of high quality. For the projects in Iowa (1,2), for example, the cement factor for the various projects varied from approximately 600 pounds of

cement per cubic yard of concrete to as high as 825 pounds per cubic yard. Water-cement ratios have generally been between 0.36 to 0.43 (See Appendix A, Bibliography 1,2,3). Superplasticizers have been used as one method of providing the desired workability without increasing the water-cement ratio. Air-entrainment percentages of between 3 and 8 percent were specified for the concrete in all overlays evaluated.

Typical specifications for the concrete recommended by the Iowa Concrete Paving Association (ICPA) are given in Appendix A. Mixes A and B shown in these specifications are typical of the concrete proportions used in the jobs visited. Flexural strengths achieved with the indicated curing periods are shown in Figure 5.1.

Concrete for the bonded overlay at Champaign-Urbana Willard Airport was specified to meet the FAA requirements for P-510, with a cement factor of six (6) bags per cubic yard (584 pounds per cu. yd.) (21,22,41). The specified air content for the concrete was between 3 and 6 percent, with a water-cement ratio of between 0.34 and 0.37. Specified slump range for the Willard Airport project was between 2 and 5 inches.

One parameter which must be kept in mind in the design of concrete mixes is the relationship between the overlay thickness and the maximum particle size. If overlay thicknesses of 2 inches or less are used, then a maximum particle size for coarse aggregates should be 3/4 inch or less. In general the maximum particle size in the mix should be no greater than 1/2 the nominal thickness of the bonded overlay (7).

5.2 Grout

Grouts used for bonding the overlay to the existing pavement consisted of two types; either a sand-cement slurry or a neat cement (1,2,3,21,22).

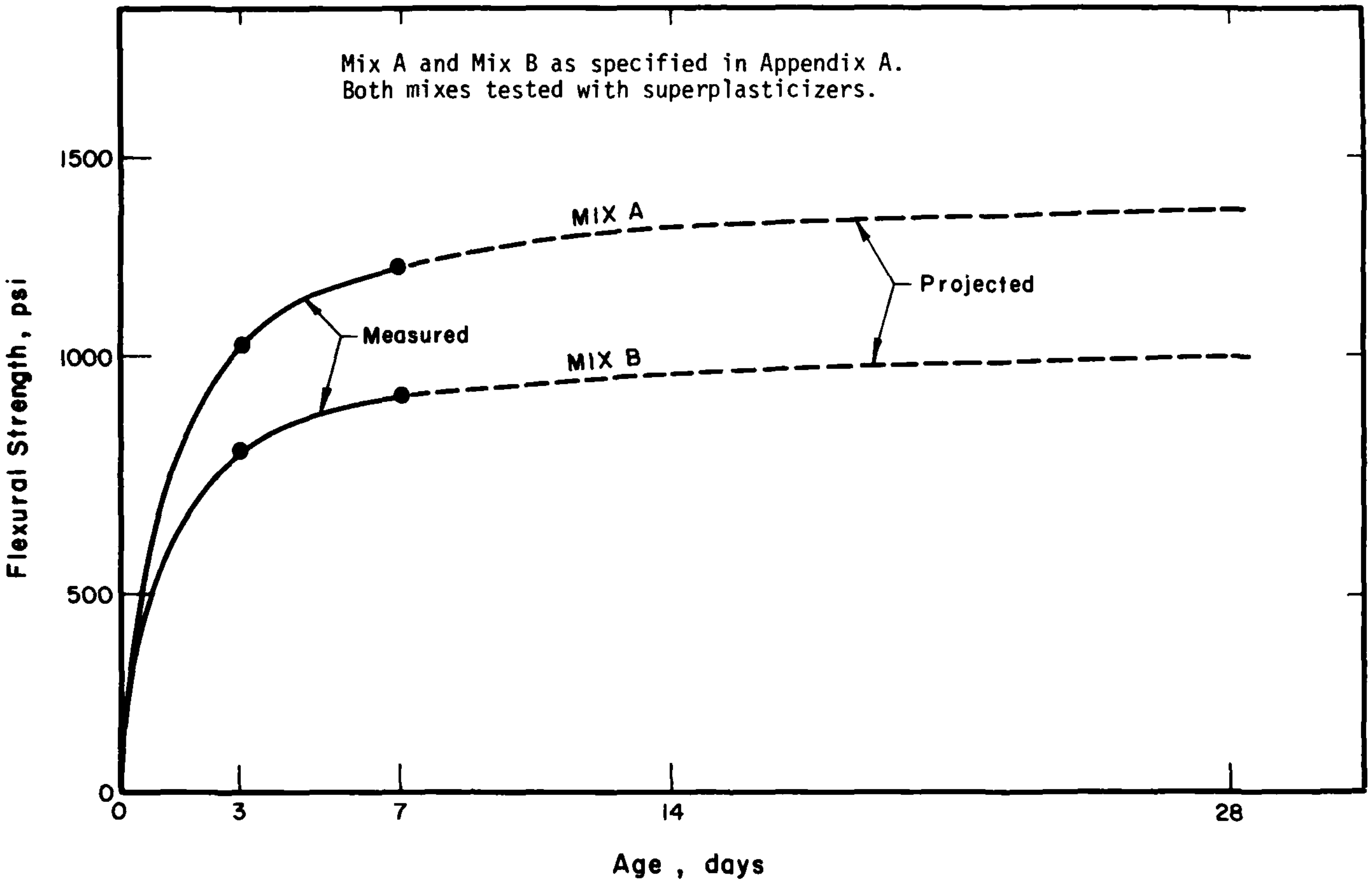


Figure 5.1. Typical Age-Strength Relationship for Concrete in Overlay on U.S. 20, Near Waterloo, Iowa (2, 3).

The sand-cement slurry consisted of equal parts of portland cement and concrete sand with sufficient water to form a stiff slurry. The consistency of the slurry was such that it could be spread with stiff brooms to form a thin, uniform coating over the entire surface of the existing pavement with no tendency to run or pond in the low places on the existing slab. The maximum water-cement contact time for the grout prior to placement of the overlay was usually specified as 90 minutes. However, some grouts were held in the mixing truck as long as three hours without apparent harm to the bond (2).

A neat cement grout consisting of portland cement and water was used as the bonding agent on at least one overlay with good success (Ref. 2). It was the intent to apply the neat cement grout with a pressure spray. During construction, however, the grout was applied with stiff brooms and squeegees in the same manner as the sand-cement slurry, and with apparently equal effectiveness as discussed in Section 4.2. (Note: See Appendix B, Iowa I-80 for discussion and photographs of the use of sprayed on grout).

5.3 Cement

Portland cement used for both the concrete overlay and the grout was specified as Type I. Type III (high early strength) was specifically prohibited by some specifications (3).

5.4 Admixtures

All concrete was specified to have air entrainment from approximately 3 to as high as 8 percent. Water reducing and set control agents were also allowed by most specifications with approval of the engineer. Super water reducers (superplasticizers) were specified for some projects (1,2,3) but not specified for others (41). Since each of the super water

reducers has its own characteristics, approval and conditions for usage of each agent must be obtained on a job-by-job basis.

5.5 Areas of Potential Research Needs

Some areas of potential research needs with respect to concrete mix design and grout mixes are:

a. What are the economic advantages of using high cement factor, high strength concrete on bonded concrete overlays?

b. Can high early strength cement be used in the construction of bonded concrete overlays?

c. Will shrinkage compensating cements be effective in construction of bonded concrete overlays?

d. Which additives are most cost-effective for use in bonded concrete overlays? That is, are superplasticizers cost-effective and if so, under what conditions? Are other additives necessary or cost-effective?

e. What grout mix is most cost-effective? Both sand-cement slurry and neat cement grouts have been effective in the projects visited, but no attempt has been made to evaluate the relative cost-effectiveness of the two types of grout in conjunction with the construction procedures most effective with each type grout.

f. Are grouts needed to provide a reliable bond between the overlay and the existing pavement?

The above items of potential research needs are not listed in their order of importance.

6.0 CURING

Curing procedures for bonded concrete overlays should be essentially the same as curing for new concrete pavements. All projects visited in Iowa used the liquid membrane-forming compounds applied at a rate of 0.13 gal per square yard. This is approximately twice the normal application rate for such compounds (1,2). To prevent running at this rate of application the compound was applied in two stages with a curing period of approximately one-half hour between. Curing at the Willard Airport was with the liquid membrane-forming compound (Federal Spec. TT-C-800, Type 2) applied at the normal rate (41).

Wet burlap was used to moist-cure a part of one project in Iowa and gave excellent results (51). Project engineers indicate they did not feel this method of curing produced sufficiently superior results to warrant the added curing cost.

While none of the projects visited has used alternate methods such as plastic sheeting, or cotton mats for curing, there is no reason why these methods would not also be effective for curing the overlay concrete. Felt (7) reported the use of wet cotton balls for 3 days, followed by a liquid membrane-forming compound. One important factor to keep in mind with bonded concrete overlays is a need to minimize shrinkage to prevent cracking of the overlay. Thus, effective curing procedures which minimize moisture loss are required and any curing procedure which does this should be satisfactory.

7.0 JOINT SPACING AND TYPE

7.1 Transverse Joints

Joints in bonded concrete overlays must be of the same type and coincide exactly with joints in the existing pavements. For example, Figure 7.1 shows the placement of an expansion joint in the bonded overlay directly above an expansion joint in the existing slab at Willard Airport. Contraction joints were sawed directly above existing contraction joints on this project. No attempts have been made to provide additional joints in the bonded overlays at locations intermediate to the joints in the existing pavement.

All major joints and cracks in the existing slab should be presumed to eventually reflect through the overlay. If the overlay is thin, most of these will reflect through within a very short period after construction. If a joint is not placed directly over the existing joint, the existing joint will likely reflect through as a crack as shown in Figures 7.2 and 7.3. While the reflected crack may perform as effectively as the sawed joint shown in Figure 7.4, it cannot be filled or sealed effectively and does not look as finished as sawed joints.

Sawed joints in bonded concrete overlays also present some problems. Figures 7.5 and 7.6 show a sawed joint with a secondary crack adjacent to the saw cut. This type of distress appeared in over 25 percent of the sawed contraction joints in the thin overlays in the Clayton County project (2), but was found to be less severe in the thicker overlays. At Willard Airport, where the bonded overlay was nearly 8 inches in thickness, only 11 joints out of several hundred in the project exhibited the secondary joint

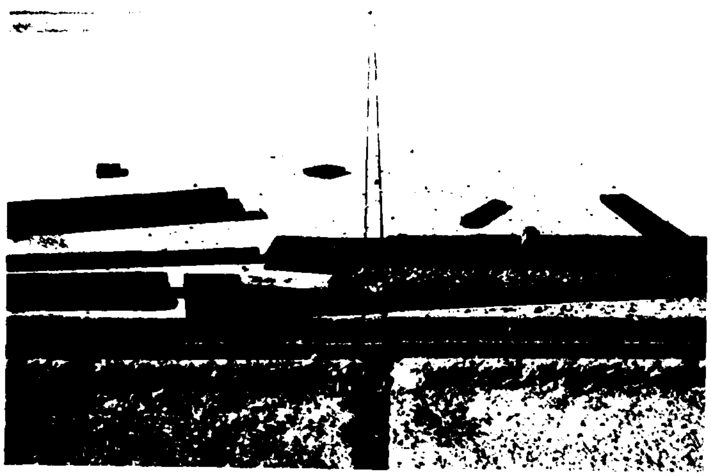


Figure 7.1. Provision of an Expansion Joint in the Bonded Concrete Overlay at Willard Airport, Illinois.

Figure 7.2. Reflection Crack from a Transverse Joint in the Base Slab, a Typical Non-Sawed Joint at Clayton Co., Iowa, View 1.

Figure 7.3. Reflection Crack from a Transverse Joint in the Base Slab, a Typical Non-Sawed Joint at Clayton Co., Iowa, View 2.

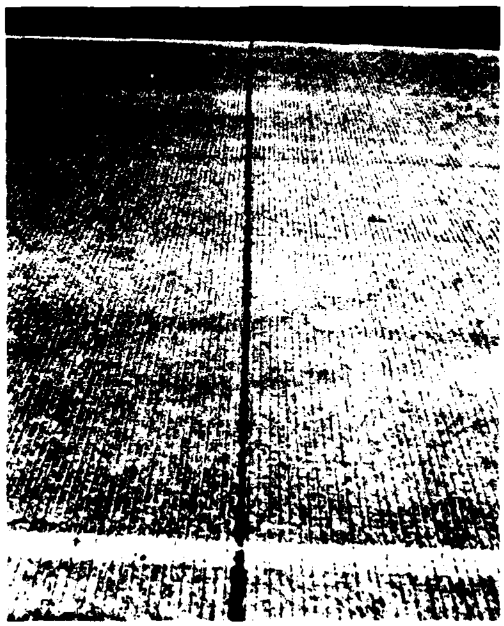


Figure 7.4. Sawed Transverse Joint in Overlay at Clayton Co., Iowa.

Figure 7.5. Sawed Transverse Joint in Overlay that has Developed a Secondary Joint Crack (Clayton Co., Iowa), View 1.

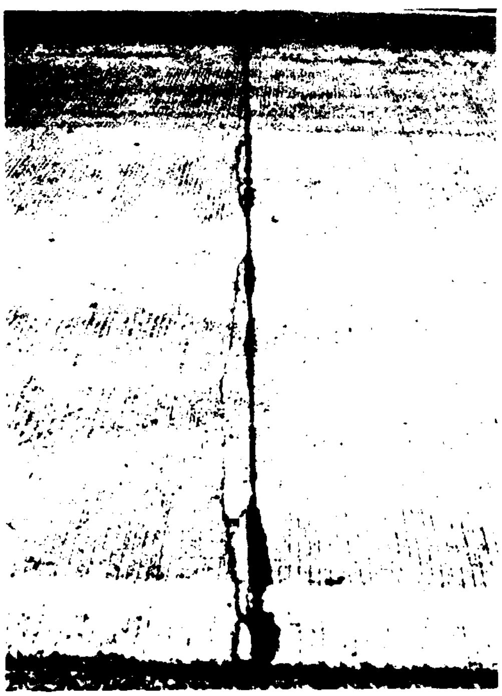


Figure 7.6. Sawed Transverse Joint in Overlay that has Developed a Secondary Joint Crack (Clayton Co., Iowa), View 2.

cracking (21,22). Similarly, in the Clayton County project (2) the 5-inch-thick overlays showed significantly less secondary cracking than the 2-inch-thick overlays. This type of secondary cracking is of some concern since there is a tendency for the portion of the concrete between the saw cut and the crack to break off, leaving an open and ragged spalled joint.

Causes of the formation of the secondary joint crack in bonded concrete overlays are not known for certain. One assumption is that these cracks form, or are at least initiated, before the saw cuts are made. Cracks may, for example, start near the joint in the existing slab almost immediately after the concrete overlay is placed, and then propagate to the surface with time. The reason for the greater frequency of secondary joint cracks in the thin-bonded overlays is that with a thin-bonded overlay the path from the initial crack tip to the surface is much shorter and thus there is less opportunity for the crack path to adjust to the saw cut location. Figure 7.7 shows a schematic of this phenomenon.

It has also been hypothesized that if the joint or crack in the existing slab is badly spalled and not filled prior to overlaying the thicker concrete required in the overlay, replacing the spalled concrete may cause the crack to initiate at a point other than directly over the existing joint.

To eliminate the secondary joint cracking problem, it will be necessary to form the weakened plane in the overlay at a much earlier age. If, as hypothesized above, the crack is initiated at an early age in the concrete, then it is probable that it will be necessary to form the joint while the concrete is still plastic. Even if an attempt is made to saw these joints at an earlier age, the crack would likely have already been initiated by the time the concrete is hard enough to permit sawing. Also, just getting

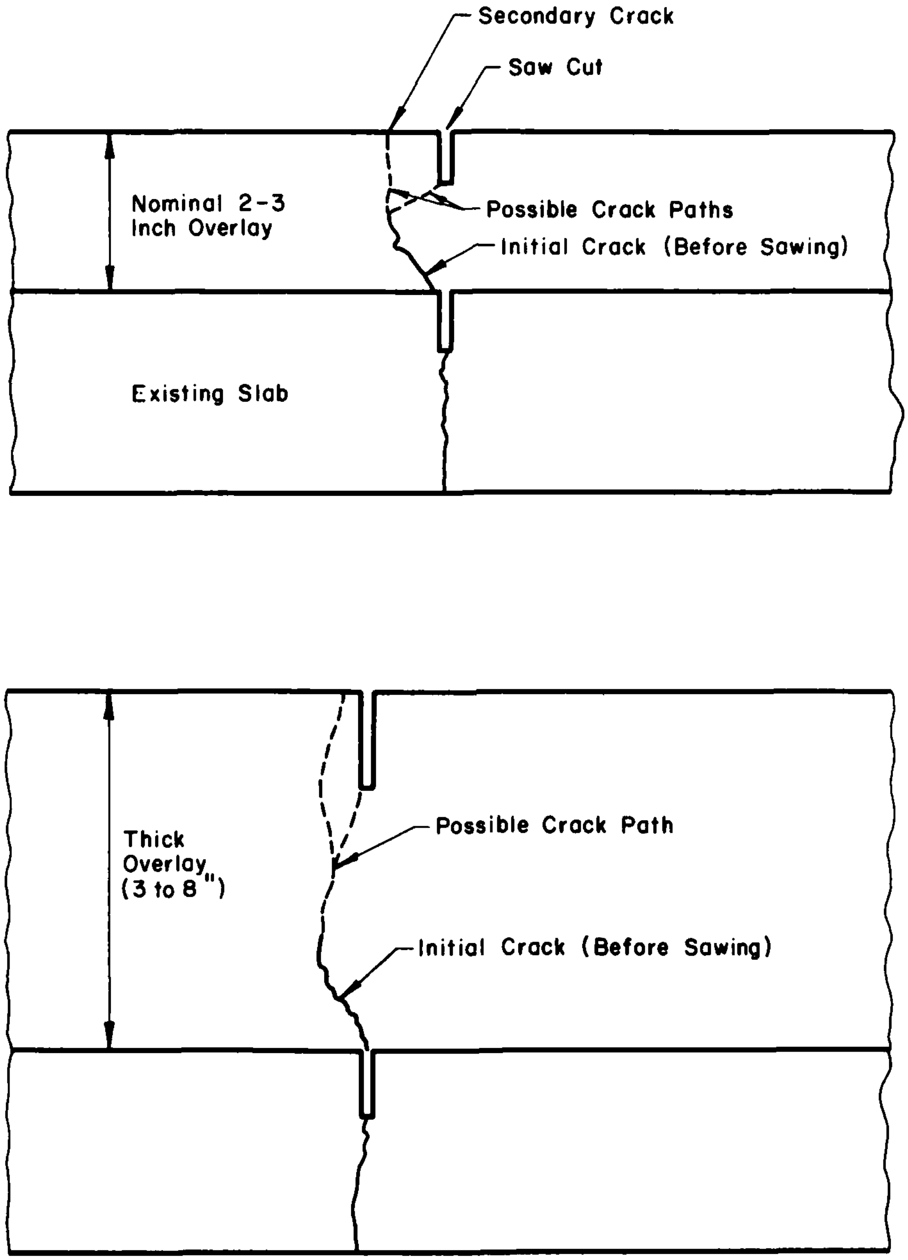


Figure 7.7. Possible Cause for Secondary Cracking.

enough manpower and saws on the job to saw all joints at the same relative age would be virtually impossible and prohibitively expensive. Full-depth sawing of the joints in the overlay has been proposed, but has not been tried and evaluated for effectiveness in eliminating secondary joint cracking. Full-depth sawing will obviously eliminate all load transfer in the overlay.

Load transfer systems are not normally installed in thin-bonded overlays. If the bonded overlay is of sufficient thickness to accommodate load transfer systems, such as dowel bars, then the type of load transfer devices in the overlay should be the same as the load transfer devices in the existing pavement. Joints with dissimilar load transfer efficiencies may cause delamination of the overlay and base pavements.

For original plain jointed concrete, there is no reason to provide extra expansion joints in the overlayed pavement (other than what existed in the original slab). Added expansion joints result in the opening of other joints placed between the expansion joints, with a resulting loss in load transfer. When the original slab is a jointed, reinforced concrete with a history of blowups, it is good practice to provide expansion joints every 1000-1500 feet.

7.2 Longitudinal Joints

Longitudinal joints in the thin-bonded overlays placed in Iowa were not sawed, except for a short section on the Clayton Co. Project (Fig. 3.8). When the existing slab had a centerline joint, this joint reflected through as a crack which meandered in a narrow path near the center of the slab as shown in Figures 7.8 and 7.9. In some instances (1,2) this crack was maintained in a tightly closed position by use of tiebars placed in the

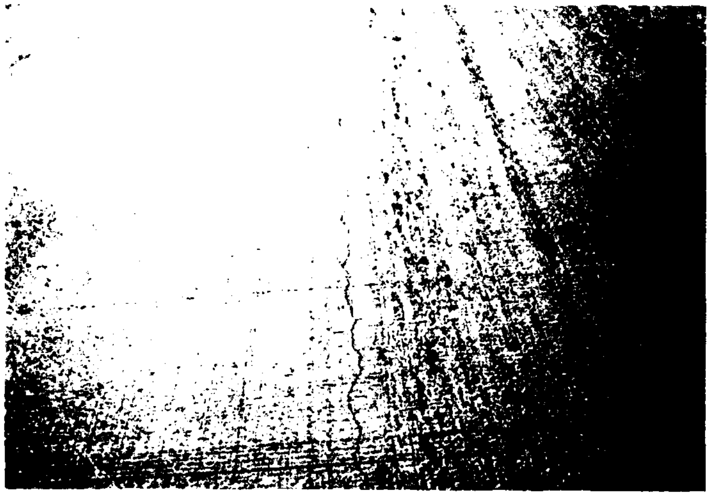


Figure 7.8. Reflection Crack in Overlay from Longitudinal Joint at Waterloo, Iowa.

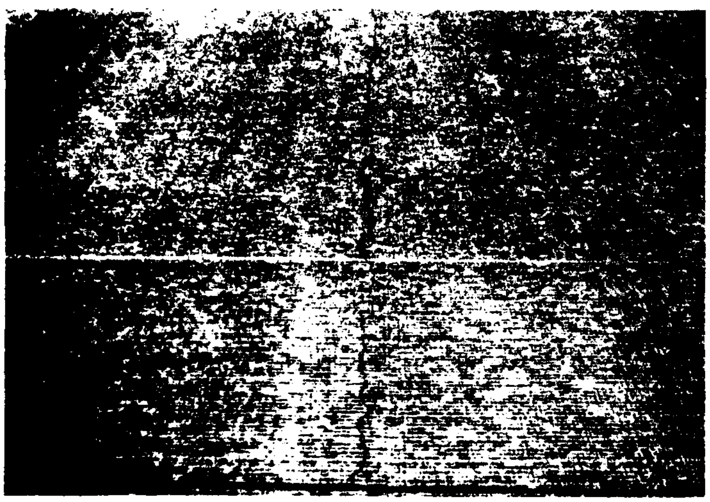


Figure 7.9. Reflection Crack in Overlay from Longitudinal Joint at Clayton Co., Iowa.

overlay across the centerline joint. This is possible only when the overlay is of sufficient thickness to accommodate the installation of tie bars.

7.3 Cracks

As discussed earlier, cracks in the existing pavement will reflect through. With the thin-bonded overlays (2 to 3 inches) the cracks will reflect through very shortly after the overlay is placed (within a year). With the thicker overlays there may be a time delay of several years before the cracks reflect through to the surface. At Willard Airport, where bonded overlay of approximately 8 inches was used, tie bars were placed in the overlay over locations where intermediate joints were formed in the existing pavement as a result of partial slab replacement. These joints have not reflected through after approximately one year of service.

7.4 Areas of Potential Research Needs

Treatment of the joints and cracks appears to be one of the areas in most critical need of research. With thin-bonded overlays of less than about 4 or 5 inches all cracks must be assumed to reflect through the overlay. Therefore, it will be necessary to remove and replace all cracked slabs if a crack-free overlay is desired. It is not clear how thick the overlay must be to prevent reflection of a crack or how effective reinforcing is in retarding the crack deterioration. Problems of secondary cracking parallel to sawed joints are also serious problems which need to be resolved. With these problems in mind, the following areas of potential research needs are defined:

a. For thin-lift bonded concrete overlays, what methods of joint forming must be used and when to prevent secondary cracking? How thick must the overlay be before sawing of joints can be used without significant secondary joint cracking?

b. Can bonded overlays be applied which will reflect cracking in the existing slabs yet remain tight and not spall? If so, what procedures must be used and under what conditions?

8.0 PERFORMANCE OF BONDED CONCRETE OVERLAYS

Bonded concrete overlays have been used to rehabilitate existing concrete pavements for more than 60 years. Use of the bonded concrete overlays has been erratic, however, and most projects have been more in the nature of experimental projects rather than as production projects. Despite the experimental and sporadic nature in the use of this method of rehabilitation, sufficient evidence and data are available to draw conclusions with respect to the potential of bonded concrete overlays and the critical features affecting performance.

8.1 Performance from the Literature

Properly bonded overlays and the base pavement behave structurally as a composite system with behavioral characteristics similar to that of a monolithic system of the same thickness. Felt (7) reported test results on beams and slabs with bonded overlays as follows:

> "It is significant to report that the strength of the 12-inch two-layer slabs where secure bond was obtained was equal to the theoretical strength of a monolithic slab of 12-inch total thickness. This work substantiates laboratory studies which showed that two-layered bonded beams had bending strength approximately equal to full-depth beams of the same total thickness."

The influence of using a higher modulus concrete in the overlay than that in the existing pavement has little apparent effect on the behavior of the composite slab (7).

Performance of bonded concrete overlays has generally been excellent, provided the existing pavement is structurally in good condition (or was repaired to a good condition), the existing concrete is sound, good bond is achieved between the existing concrete and the overlay, and an

adequate jointing system is provided in the overlay. Delamination due to loss of bond or due to failure in deteriorating concrete, and reflective cracking through the overlay over cracks in the existing slabs are the primary types of distress associated with the bonded concrete overlays. Some specific examples from the literature and from projects visited by investigators for this study are given in this section.

Felt (7) in 1956 presented data on the performance of a number of projects after a varying period of service, some with service records as long as 40 years. The projects reported on were from a wide area including such states as Wisconsin, Minnesota, Rhode Island, Illinois, Michigan, Missouri, Nebraska, New York, Ohio, and Pennsylvania. The bonded overlays were placed using a number of surface preparation techniques and over a variety of existing conditions. The overlays were generally from two to five inches in thickness and yielded the following results.

1. Bonded concrete overlays have remained in service for up to 40 years.
2. Many of the cracks in the existing pavements reflected through the overlay, causing Felt (7) to conclude

   "There does not appear to be a simple economical method of preventing the occurrence of sympathy cracking in a bonded resurface."
3. In a number of projects where delamination occurred, the failure plane was apparently in the old concrete rather than failure of the bond per se. In several instances the need for the overlay was due to deterioration of the concrete surface in the existing pavement, indicating the presence of unsound concrete.
4. Bond failures occasionally occurred, usually initiating in the vicinity of cracks or joints. According to Felt (7), the extent of bond deterioration progresses slowly.

Gillette (8) in 1965 reported on the performance of bonded concrete overlays after 10 or more years of service. Based on this review, Gillette offers the following conclusions:

> "Bonded concrete resurfacing has performed in an excellent manner as a means of strengthening old concrete pavement, providing a new smooth surface, repairing surfaces which have popouts, or repairing and patching spalls, scaled areas, etc.
>
> Since adequate bond can be obtained with normal construction equipment and materials, chemical adhesives are not necessary. Cores obtained from projects using various methods of surface preparation indicate that a bond strength of 200 psi is adequate and that when such bond is obtained, it will endure.
>
> Evidence shows that wherever loss of bond occurs, it probably developed soon after construction; little or no growth in the loss of bond area occurs over a period of time and under traffic. A few unbonded areas, especially at corners, show evidence of needing removal and replacement in the future. Certain information has been accumulated which is common to practically every project. Here, in brief, are some of the findings.
>
> 1. It is essential to follow the recommended techniques and construction sequence to assure a successful project;
> 2. Thin watery grout or free water left standing on the surface of the base pavement tends to weaken the bond;
> 3. An adequate bond strength can be obtained, using the techniques outlined by Westall [9,10]. When such bond is obtained, shear tests cause a break in the base pavement in practically every core tested;
> 4. Some loss of bond was found on practically every project with most areas being small in size along longitudinal construction joints;
> 5. Loss of bond areas can only be found by sounding the pavement and show little or no deterioration;
> 6. No distress was observed along longitudinal construction joints which could be attributed to lack of load transfer;
> 7. Joints in the base pavement will reflect through the resurfacing and should be matched whenever possible; and
> 8. Cracks in the base pavement will also reflect through the resurfacing in most cases.
>
> The evidence gathered shows that adequate performance can be expected regardless of the thickness of the resurfacing and the type and frequency of traffic."

8.2 Recently Constructed Projects

Several recent projects in which newer methods for surface preparation were used were surveyed by the authors. Specifically, projects in Iowa (Clayton County and Waterloo) and Illinois (Willard Airport) were reviewed in some depth with respect to the surface preparation techniques used and the results obtained to determine the most cost-effective techniques using modern equipment and technology. Since these projects have been in service for only 1 to 4 years, long-term durability cannot be evaluated. It has been pointed out by other investigators that once bond is achieved, it will last; it follows that much can be learned by careful study of these projects. A field survey of the partially bonded overlays placed in Green Co., Iowa and Georgia were also conducted.

Waterloo, Iowa

In October 1976, the Iowa Department of Transportation constructed a 1500-foot-long segment of thin-lift (2-inch) bonded concrete overlay on an existing concrete slab. The project was located on U.S. 20 at the east edge of Waterloo, Iowa. The objectives of the project were as follows:

Objective 1

To determine the feasibility of proportioning, mixing, placing, and finishing a thin-lift (approximately 2 inches - 50 mm) of bonded, dense, non-reinforced portland cement concrete using conventional slip-form plant and paving equipment in resurfacing existing concrete pavements.

Objective 2

To determine the feasibility of partial-depth repair of deteriorated transverse joints in concrete pavements using a bonded, dense, non-reinforced, portland cement concrete.

Objective 3

To determine if an adequate bond between the existing pavement and an overlay of thin-lift, dense, non-reinforced portland cement concrete can be obtained. (Surface milled with Roto-Mill, Figure 2.6).

Objective 4

To determine the economics, longevity, and maintenance performance of a bonded, thin-lift, non-reinforced portland cement concrete resurfacing course as a viable alternative to bituminous resurfacing of concrete pavements.

The existing pavement was a four-lane divided roadway with 10-inch plain jointed PCC slab with a 20-foot joint spacing. The pavement was constructed in 1958, had very little slab cracking, but had serious "D" cracking at the joints (see Figures 3.1 and 3.2). Figure 8.1 shows the approximate condition of joints at the present time in portions of the same pavement which were not repaired or overlaid.

Items of work in this project included surface preparation by milling, sandblasting and airblasting, partial-depth patching at the joints to remove "D" cracked concrete; full-depth patching at selected badly deteriorated joints, and a 2-inch-thick bonded overlay. Work also included incidental sawing at transverse joints. A detailed report on this project is given in Reference 1 .

The project near Waterloo was visited in July 1979. At that time the project was just under three years old and generally in excellent condition. The only distress in this project was at the location of several full-depth

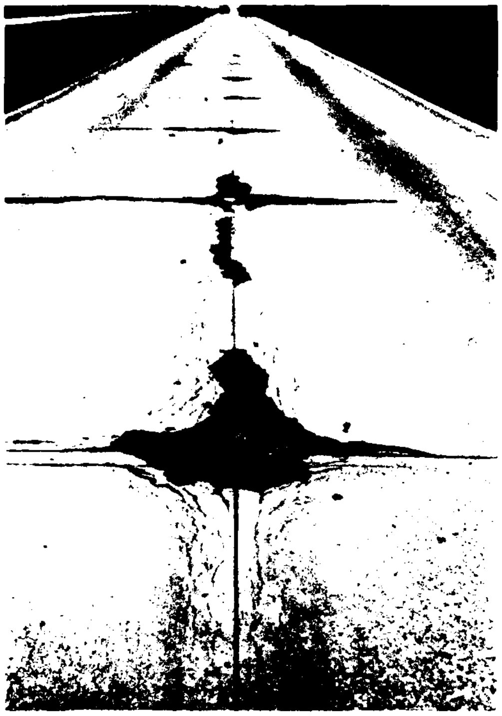


Figure 8.1. "D" Cracking in 1979 in Portions of the Original Slab at Waterloo, Iowa which were not Repaired or Overlayed.

Figure 8.2. Overall View of Waterloo, Iowa Bonded Overlay, 1979.

patches, where two parallel cracks developed some reflective cracking especially along the centerline which was not sawed (Figure 8.2) and in one area where there is some minor shrinkage cracking of the concrete (Figure 8.3). As indicated in Section 3, the bond was checked with a Delamtect approximately 6 months after construction and except for one small area there was no evidence of delamination of the pavement. Shear strengths measured on cores taken from the pavement averaged 956 psi with a standard deviation of 375 psi. The lowest shear value obtained was 210 psi. Cores were taken at 6 and 16 weeks with approximately the same results.

Several joint treatments were tried in this project. Just before the start of the overlay several joints were milled to remove the "D" cracked concrete to a depth of sound concrete, usually several inches. These joints were then filled, struck and textured, but were not overlaid. The patches were not generally sawed through the patch at the joint in the base slab but cracks were allowed to reflect through. Figure 8.4a shows a typical crack through such a patch. Some joints were milled parallel to the joint with feathered edges shown in Figure 8.4b and others milled perpendicular to the joint to form square edge joints. The two methods have given comparable results thus far.

On the U.S. 20 project some joints were sawed partial-depth through the overlay and others were not sawed but allowed to reflect through the overlay. A typical example of each type is shown in Figures 8.5 a and b. Some spalling was observed in the non-sawed joints but this was not considered a severe problem.

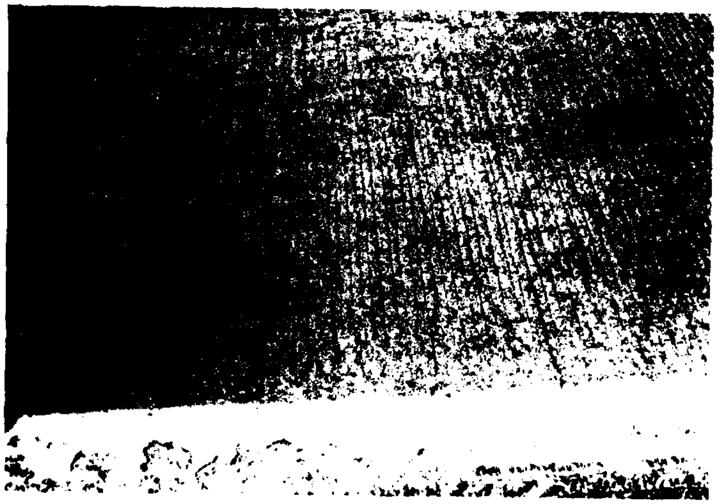


Figure 8.3. Local Area of Shrinkage Cracks on the Waterloo, Iowa, Bonded Overlay.

Figure 8.4a. Typical Crack Through a Partial-Depth Patch at Joint in Waterloo Project.

Figure 8.4b. Joint Milled Parallel to the Joint with the Gallion RP-30 Road Paver (2).

Figure 8.5a. Typical Sawed Transverse Joint in the Waterloo, Iowa, Project.

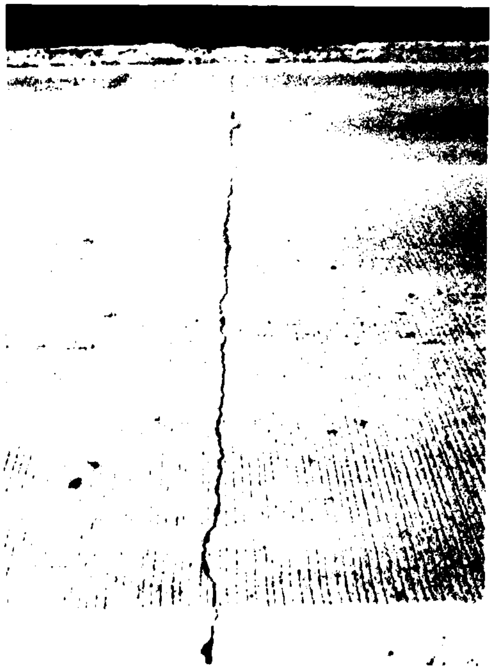


Figure 8.5b. Typical Non-Sawed Reflected Joint in the Waterloo, Iowa, Project.

Clayton Co., Iowa

A second major project in Iowa which was visited was the Clayton County Project. This project was surveyed in 1979 and is described in Reference 2. The site for this project was a 1.3-mile segment of a secondary route in northeast Iowa adjacent to the Mississippi River. The existing pavement was a 6-inch-thick concrete plain jointed slab with a 40-foot joint spacing and was constructed in 1968. A photo of broken up area of the existing slab is shown in Figure 8.6. At the time of the overlay in 1977 the Average Daily Traffic (ADT) was 650 with an Average Daily Truck Traffic of 280. The large number of trucks was generated by a grain terminal and a silica sand mine in the town of Clayton.

At the time of the overlay the concrete in the pavement was of excellent quality but was showing distress in a number of areas because of the heavy truck traffic and some distress in the transverse joints. The stated objectives of this study were as follows:

Objective 1

Determine the feasibility of proportioning, mixing, placing and finishing a thin-lift (approximately two inches) on bonded, dense, non-reinforced PCC using conventional central batch plant with transit mix trucks and slip-form paving equipment in resurfacing existing concrete pavements.

Objective 2

Determine the feasibility of partial-depth repair of deteriorated transverse joints in concrete pavements using a bonded, dense, non-reinforced PCC.

Figure 8.6. Original Base Slab at Clayton Co.,
Iowa, Showing Broken Up Area.

Objective 3

Determine if an adequate bond between the existing pavement and an overlay of thin-lift, dense, non-reinforced PCC can be obtained.

Objective 4

Determine the economics, longevity, and maintenance performance of a bonded, thin-lift, non-reinforced PCC resurfacing course as a viable alternative to bituminous resurfacing of concrete pavements.

The total 1.3-mile project consisted of a number of combinations of surface preparation, overlay thickness, reinforcement, concrete mixes, and method of joint repair. Table 8.1 gives a summary of the different treatments used on this study and the results obtained.

Overlay thicknesses varied from two to five inches. Surface preparation consisted of various combinations of surface milling, sandblasting, and water blasting. Two concrete mixes were used, one a mix C-4WR with 595 pounds of cement per cubic yard and mix C-4 SWR with 625 pounds of cement per cubic yard and a superplasticizer. Twenty seven (27) transverse joints received partial-depth repair, 13 were repaired full-width, and 14 repaired one-half pavement width. Depth of repair varied with the amount of deterioration with an average depth of repair of 3 inches. Reinforcing was used only in two short areas, (1) deformed bars placed in transverse direction and (2) chain link fencing laid in the slab.

All of the surface preparations were generally satisfactory except for the section in which water blasting alone was used. When water blasting alone was used, a small amount of delamination was observed in which the overlay was broken into small pieces. Such distress was usually over relatively small areas near the edge of the pavement. A typical example

TABLE 8.1. CONDITION SURVEY OF CLAYTON CO., 1979

Concrete Overlay Thickness, in.	Surface Treatment*	Comments
2	Water blast	Reflection cracking, several areas of localized broken pieces that have debonded at edge and interior (see Figure 8.7a, 8.7b, and 8.8).
	Sandblast	Ref. cracking, secondary joint cracks, one edge debonded area (see Figs. 7.5 and 8.9).
	Milled	Ref. cracking, tight cracks and joints, no breakup or debonding (see Figs. 7.3 and 8.10).
3	Water blast	Ref. cracking, spalling (some potential for debonding) (see Fig. 8.16).
	Sandblast	Ref. cracking (some spalled), secondary joint cracking (see Figs. 7.6, 3.7, 3.8, 3.9).
4	Sandlast	Ref. cracking (some spalled), secondary joint cracking (see Figs. 8.17-8.19).
	Milled	Ref. cracking (some spalled), localized spalled transverse joint (see Figs. 2.1-2.5, 8.20).
5	Milled	Some reflective cracking, no spalling (see Figures 8.11-8.15).

* Surface treatment also included placement of 1:1 sand-cement grout.

of this type is shown in Figures 8.7a and b and 8.8. Total area with this type of distress was generally small, but does indicate a potential problem area. Distress of this type was not observed in areas where surfacing milling and/or sandblasting was used either alone or in combination, except for one or two small areas where sandblasting alone was used. One example of this distress is shown in Figure 8.9.

No difference in performance was observed between the two concrete mixes.

Reinforcement consisted of #4 deformed bars placed transversely on 30-inch centers staggered from each side of the pavement to provide double reinforcement across the centerline. With the three-inch overlays the parabolic crown of the pavement caused the bars to be near the concrete surface and a number of the bars caught on the screed pan of the paver. This problem was not as severe in the 4-and 5-inch-thick overlays. While this reinforcement did hold the cracks in the overlay tightly closed, it did not prevent the reflective cracking from occurring. There was some reduction in reflective cracking in the 5-inch-thick overlay with reinforcement.

The chain link fence experiment proved unsatisfactory.

Little difference was observed in the performance of the overlay of different thicknesses. The 5-in. overlay has reflected fewer cracks (and they have remained tight) than the thinner overlays. Those portions of the project in which the existing concrete was uncracked before the overlay remain essentially uncracked today. It can only be speculated on what the condition of the original pavement would be today if no overlay were placed. In areas of the original project that were not overlayed, the pavement has continued to deteriorate under the heavy truck traffic (see Figure

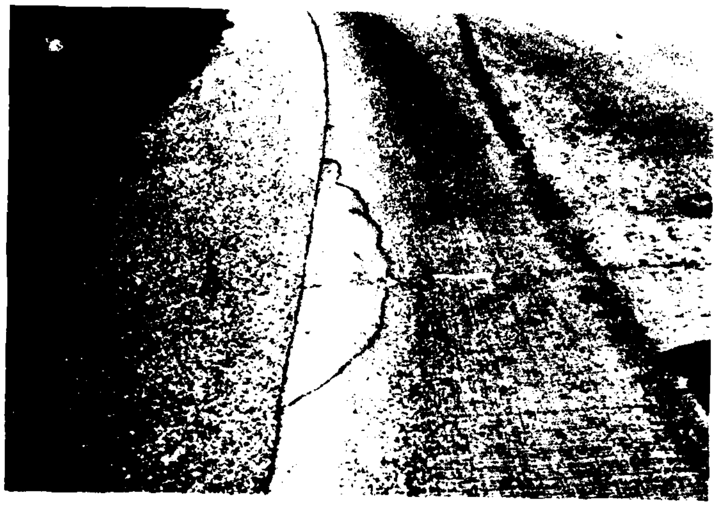


Figure 8.7a. Localized Breakup Area of 2-in. Overlay Cleaned by Water Blasting That Has Debonded at Clayton Co., Iowa.

Figure 8.7b. Closeup of Figure 8.7a.

Figure 8.8. Localized Area of Debonding of 2-in. Overlay Where Water Blasting Was Used as Surface Preparation Method at Clayton Co., Iowa.

Figure 8.9. Localized Area of Debonding of 2-in. Overlay Where Surface Preparation Method Was Sandblasting at Clayton Co, Iowa.

8.6). Thus even the two-inch overlay seems to have reduced or arrested the pavement structural deterioration, especially in areas where the original pavement was still structurally sound.

With all overlay thicknesses, most cracks in the original pavement have reflected through. There is some evidence that the time required for the crack to reflect through is extended somewhat with the thicker-overlays, but after approximately two years of service most cracks have reflected through. Typical reflected cracks for 2- and 5-inch-thick pavements are shown in Figures 8.10 and 8.12.

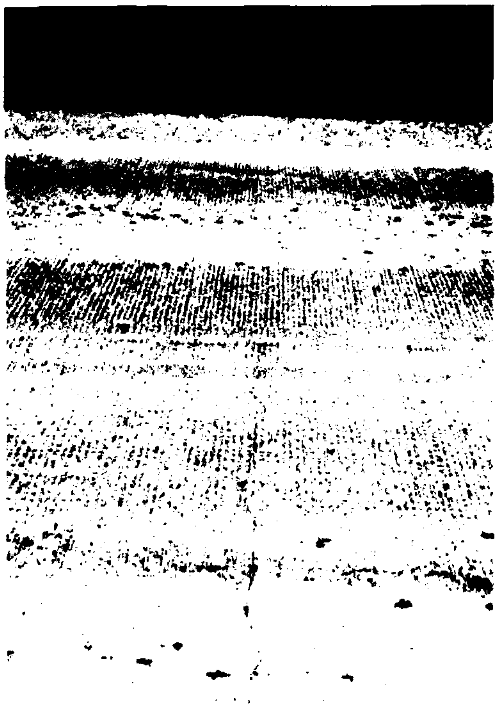


Figure 8.10. Reflective Crack in 2-in. Overlay with Sandblasting as Surface Preparation.

Overall, the current status of this project indicates that reliable bond between the existing pavement and the overlay can be achieved by milling or sandblasting the surface or by a combination of milling, sandblasting and water blasting. Water blasting alone may not have pro-

Figure 8.11. Diagram of Crack Pattern in Original Slab, That Reflected Through Overlay.

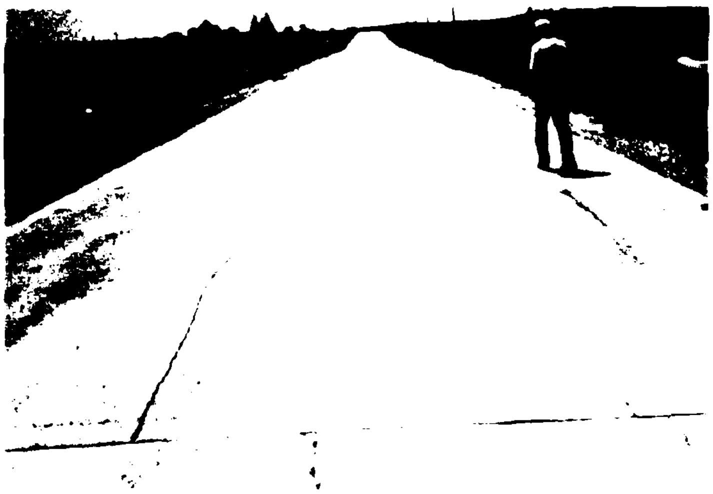


Figure 8.12. Reflective Cracking of 5-in. Overlay in Figure 8.11.

Figure 8.13. Sawed Transverse Joint in 5-in. Overlay at Clayton Co., Iowa.

vided a reliable bond even though the bond tests indicated an average high shear (see Section 2.0).

Application of thin-lift bonded overlays to sound concrete slabs will apparently increase the structural capacity of the pavements. Application of the overlay to cracked and broken slabs is not practical, however, as the cracks will quickly reflect through the overlay. Partial-depth patching of joints by milling down to sound concrete before overlaying is a viable method of joint rehabilitation.

Performance of the joints and the problems related to the secondary cracking parallel to the sawed joints are discussed in Section 7. In general the problem of secondary cracking is more severe in the thinner overlays than in the thicker overlays.

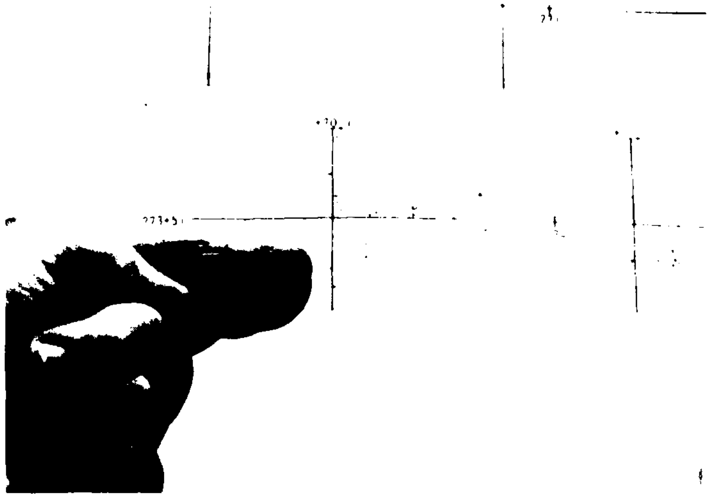


Figure 8.14. Diagram of Cracking in Original Slab That Has Not Reflected Through Overlay.

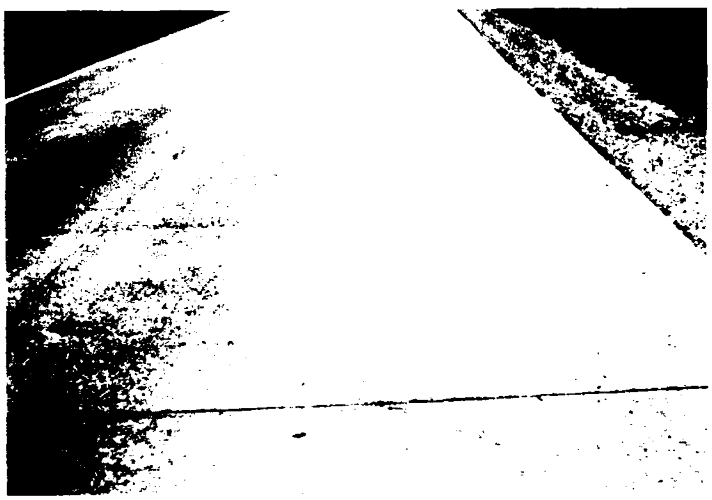


Figure 8.15. No Reflective Cracking in 5-in. Overlay of Slab Shown in Figure 8.14.

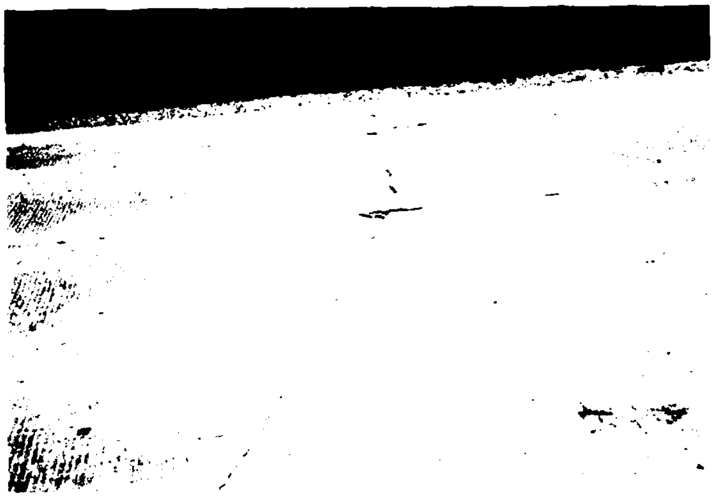


Figure 8.17. Diagram of Cracking in Original Slabs Prior to Placing 4-in. Overlay.

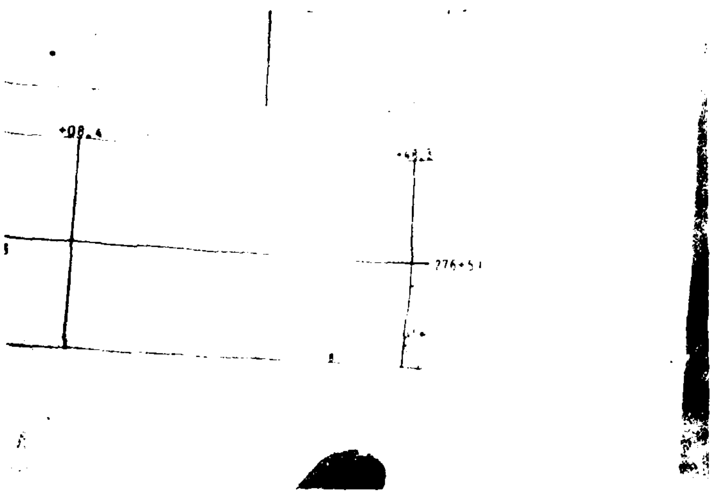


Figure 8.16. Cracking in 3-in. Overlay: Crack at Top of Photo Is Reflective (Spalled), Crack at Bottom of Photo Is New, Non-Reflective Crack (Non-Spalled), Surface Preparation is Water Blasting.

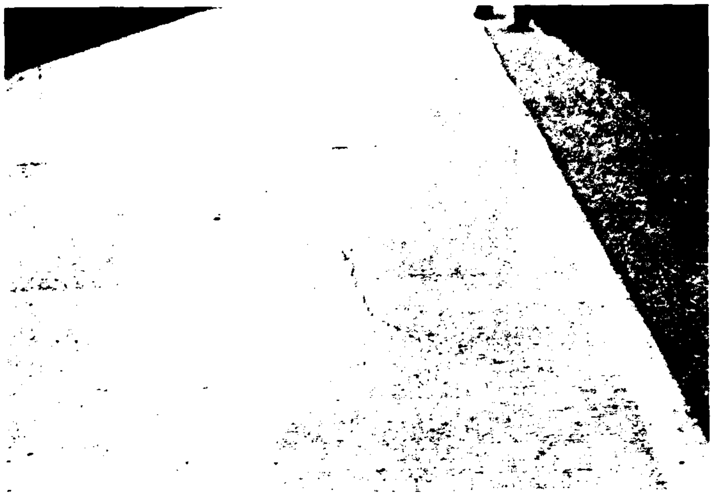


Figure 8.18. Reflective Cracking Through 4-in. Overlay for Slab Shown in Figure 8.17; Surface Preparation Was Sandblasting.

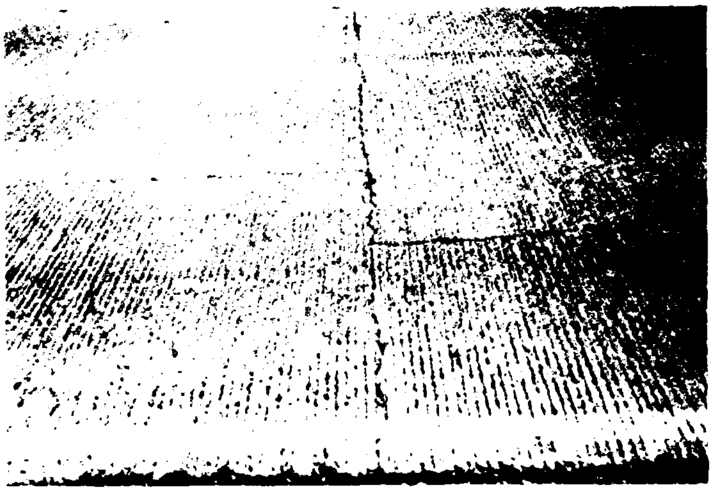


Figure 8.19. Reflective Cracking Through 4-in. Overlay for Slab Shown in Figure 8.17.

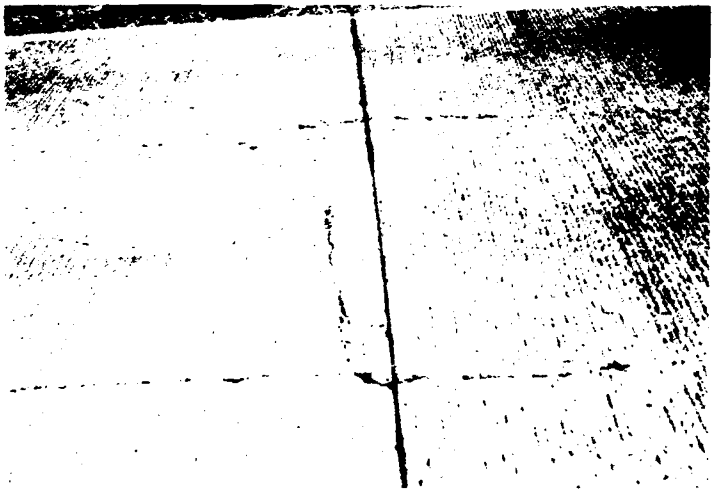


Figure 8.20. Localized Joint Spalling in 4-in. Overlay in Area Surface Caused by Mismatched Joints (Note: There Is a Non-Aligned Joint in the Original Slab Immediately Beneath the Transverse Crack Outlining the Spall).

Willard Airport, Illinois

A recent bonded overlay project was the strengthening of runway 4-22 at Champaign-Urbana Willard Airport. In this project the central 75 feet of the 150-foot-wide runway was strengthened by applying a nominal 8-inch-thick bonded concrete overlay. Partially bonded overlays were added as tapered sections to the outer 37-1/2 feet to either side of the central keel section. A full description of this project is presented in Reference 22.

The primary objective of this project was to strengthen a structurally sound, but somewhat inadequate pavement. The existing pavement was an 8-inch-thick jointed PCC with 20-foot joint spacing. The pavement was constructed in 1944, and the concrete in the existing slabs was sound and of excellent quality. Heavy aircraft had caused some broken slabs, which were removed full depth and replaced. In some instances only a portion of the slab was replaced and in such instances a secondary butt joint was placed at an intermediate point between existing joints. Also, slabs with a single, non-working crack were not replaced but were paved over.

Joints were matched by type and position. Contraction joints were sawed partial depth at all normal joints in the existing pavement and expansion joints sawed and placed over all expansion joints in the existing slab (Figure 7.1). Joints were not sawed, however, at the secondary butt joints produced by partial-slab replacement or over the non-working cracks. In these latter instances tie bars approximately 3 feet long were placed at 30-inch centers in the overlay across the joints or cracks.

Surface of the existing pavement in the 75-foot keel section was prepared by milling the surface to a depth of 1/2 inch and cleaned by power sweeping

and water blasting the milled surface. (See Figures 2.9 to 2.11). A sand-cement slurry was applied to a dry pavement surface and spread with stiff brooms and squeegees just before application of the concrete (Figures 4.2 and 4.3). The allowing of concrete trucks to back over the grouted surface was one point of concern. This concern was greatest where the grout was tracked onto the previously prepared but ungrouted surface and was allowed to "set up" on the pavement without proper clean-up. No apparent delamination has resulted from this grout smearing.

Cores were taken from the pavement and tested in direct shear at the bond interface and in the old and new concrete. Some problems were encountered in taking the cores because of the core length (16 inches). In some instances the cores would "bind" near the top of the bit and would shear off the cores by twisting. Failure of these twisted cores was usually near the bond interface, but frequently failed in the adjacent concrete. Cores that were recovered were tested in shear with the following results:

Location of Shear Plane	Maximum Shear Average (psi)	Maximum Shear Coef of Variation (%)
In overlay concrete	1183	16
Along bond face	641	31
From existing slab concrete	1709	10

These results indicate that the bond strength is well above the 200 psi some investigators believed to be adequate (1,8,27,30). The results also indicate that the shear strength at the interface is less than the strength of either the old or new concrete and has a significantly higher variability. From careful inspection of fracture planes at the bond interface, it appears that in many instances the aggregate near the interface fractured rather than failure of the bond between the grout and the old or new

concrete. Perhaps the milling operation partially fractured some of the aggregate without completely removing the fractured particles.

One area of concern due to the milling operation was the spalling along the joints and especially along the transverse joints. In some instances the spalls were of significant size (up to 2 inches) and all were not removed from the joint cracks before overlaying (see Figure 2.8). These have caused no apparent problems to date and may have no detrimental effect on the ultimate pavement performance.

The overlay at Willard Airport has been in service for approximately one year (Fall 1978 to present). The overlay appears to be performing as designed and no significant problems have been noted. The only minor problem noted is that eleven of the sawed transverse joints have some secondary cracks similar to those described earlier. While these secondary cracks are of some concern, they constitute a very small percentage of the joints in the project. No evidence of delamination has been noted in the bonded keel section of this project.

<u>I-85 Atlanta, Georgia</u>

Several types of partially bonded concrete overlays were placed on Interstate highways near Atlanta, Georgia. The sections on I-85 north of Atlanta were constructed in 1975 and include CRCP overlays (3, 4, 5, and 6 in. thick), and plain jointed concrete (with doweled joints spaced at 15 and 30 ft). Several other projects have also had their surface milled to remove transverse joint faulting. One 7- and one 8-inch CRCP overlay was placed south of Atlanta in 1971. The original slabs were plain jointed concrete with 20- to 30-ft joint spacings. No attempt was made to bond these overlays to the existing slab, since the slab was only swept before the overlay was placed.

Even though these overlays were not fully bonded, some important findings were obtained that may be applied to the performance of bonded overlays:

1. The 3- and 4.5-in. CRCP overlays were structurally inadequate for the very heavy truck traffic on I-85. Punchouts and breakup areas initiated primarily above transverse joints. A few punchouts in their initial state also were observed in the 6- and 8-in. CRCP overlays. Wide cracks were formed in the overlay above the transverse joints in the base slab.

2. The plain jointed 6-in overlay over the original 8-in. plain jointed concrete performed very well, but when the joint spacing matched that of the existing slab (i.e., 30 ft), an intermediate transverse crack occurred in about 40% of the slabs where an intermediate joint was sawed at 15-ft intervals; only a few mid-slab transverse cracks occurred.

3. Dowels can be placed in concrete overlays 6-in. thick without significant difficulties.

9.0 REINFORCEMENT IN BONDED OVERLAYS

One of the major problems in bonded overlays is the reflection through the overlay of almost every crack in the existing slab. One potential way to deal with this problem is to place reinforcement in the bonded overlay that would hold the reflected crack tight and reduce the amount of spalling. These are two general ways to reinforce the bonded overlay: (a) mesh or deformed bars and (b) steel fibers.

One recent attempt was made to utilize some reinforcement in a bonded concrete overlay. The Clayton, Co., Iowa project (2) included three 100-ft test sections of transverse reinforced overlay. The sections contained transverse No. 4 reinforcing bars, 12 ft long placed 30 inches on center and staggered from either side of the pavement to provide double reinforcement across the pavement centerline (22-foot-wide slab). Three 100 ft test sections were constructed in 3-, 4-, and 5-in.-thick overlay sections. This reinforcement was used primarily in areas in which the existing slab was broken up to the extent where full-depth patching was the only other logical alternative. The reinforcement did not prevent reflective cracking through the overlay, as most of the original cracks reflected through. The cracks in the test areas appeared reasonably tight but with some spalling.

Several engineers who have worked with bonded concrete overlays suggested to the authors the use of fibrous concrete for the overlay. Unfortunately, no segments of fully bonded concrete overlay have been constructed using fibrous concrete. Several partially bonded overlays have been constructed using fibrous concrete, but this is considerably different than a fully bonded overlay. One such project was constructed in Green Co., Iowa in 1973 (50). Actually, an attempt to develop a bond was made by placing

a cement paste on a surface that had been swept and wetted. No testing of the bond was made after construction, but in 1978 a Delamtect device commonly used to locate delaminations in bridge decks was used on the project over the outside wheel path. The fibrous concrete overlay was found to be almost completely delaminated or debonded from the base pavement. The "bonded" sections exhibited no greater degree of bonding than the "partial" (overlay placed on swept existing slab) or "unbonded" (polyethylene sheet) sections. However, the performance ratings of the fibrous concrete sections after 5 years, where the only variable was the type of bonding, showed that the bonded overlays exhibited better performance than the partial or unbonded sections (50). Typical distress in the 2- and 3-inch-thick sections was longitudinal cracks (particularly over the widening sections in the original slab). Some transverse cracks also occurred. Typical photos of the project after 6 years are shown in Figures 9.1 and 9.2. Other factors that influenced performance were thickness of the overlay (better performance with 3-in. than 2-in. thickness) and the steel fiber content (better performance with 160 lbs. per cubic yard than 60 or 100 lbs. per cubic yard).

Figure 9.1. Photo of 2-in. Fibrous Concrete Overlay Containing 160 lbs of 1-in.-Long Fibers Per Cubic Yard of Concrete after 6 Years of Service (Green Co., Iowa, 50).

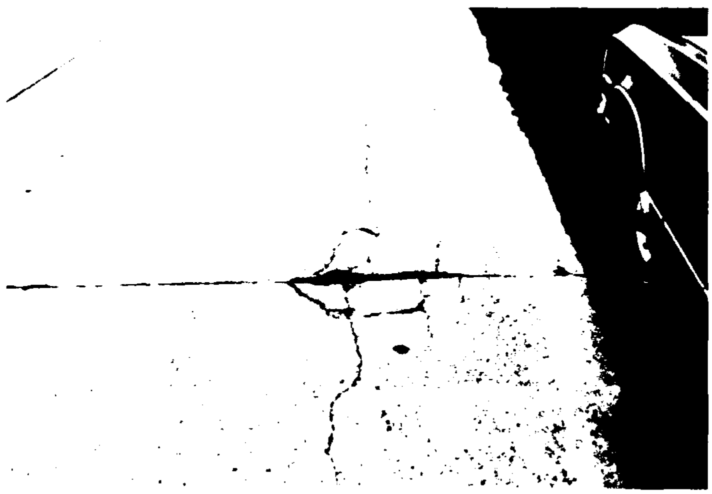


Figure 9.2. Photo of 3-in. Fibrous Concrete Overlay Containing 60 lbs. of 1-in.-Long Fibers Per Cubic Yard of Concrete after 6 Years of Service (Green Co., Iowa, 50).

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 Conclusions

Use of bonded, thin-lift PCC overlays to rehabilitate concrete pavements is not a new idea. There are reports in the literature which document the use of this concept as far back as the early 1900's. The problem with this approach has always been that of achieving a reliable bond between the existing pavement and overlay. With the introduction of the cold milling machines, surfaces can now be prepared in a manner to facilitate bonding economically and in an environmentally acceptable way. Currently, the use of bonded, thin-lift PCC overlays to rehabilitate and/or strengthen existing concrete pavements is a viable alternative to other rehabilitation techniques.

Bonded concrete overlay is not a panacea for all concrete pavement rehabilitation. As indicated in this report, there are conditions for which application of a bonded concrete overlay is a waste of money and effort. In particular, if the existing pavement is not structurally sound and is badly cracked, application of bonded concrete overlay is an impractical solution. Conversely, if the existing pavement is basically sound with some areas of deterioration and surficial scaling and spalling, then the use of a bonded concrete overlay may be the most economical and most environmentally acceptable solution.

Structurally, bonded concrete overlays are equivalent to monolithic slabs with a thickness equal to the base pavement plus the overlay. Obviously, if the base slab is cracked then the structural capacity of the system is similar to a monolithic slab cracked partially through. Under

such circumstances, it would be expected that the cracks would propagate to the surface. Similarly, it is expected that cracks or joints in the base pavement would propagate through the overlay. This, in fact, is what has been observed.

Since joints and cracks in the existing pavement will normally reflect through the overlay, it follows that joints in the overlay should coincide with joints in the base pavements. Additional study is needed, however, to determine the best way to form joints in the overlay in order to eliminate the secondary joint cracking, especially in the thin-lift overlays.

As indicated earlier, development of a reliable bond over the entire surface is the key to the performance of bonded overlays. It has been demonstrated that a reliable bond can be developed by combinations of cold milling and/or sandblasting the surface of the existing pavement plus the application of a grout. The optimum or most economical combinations for surface preparation have not been established.

Performance of bonded, thin-lift concrete overlays has generally been excellent, provided the conditions outlined above and in the body of the report with respect to the soundness and condition of the existing pavement are met. There are, however, some areas of needed research which might improve the performance, reliability, and economic competitiveness of thin-lift, bonded concrete overlays.

10.2 Recommendations for Needed Research

The following recommendations for further study are based on the authors' observations of specific problems and are essentially in order of priority on the basis of which solutions might provide greatest return for a nominal research effort:

1. One of the most critical problems to be resolved is the problem of the secondary joint cracking in the thin-lift overlays. Clearly, if such secondary cracking occurs, it will lead to severe joint spalling with concomitant maintenance problems. Thus, alternate ways of forming the joints in bonded overlays must be found to eliminate this form of distress.

2. The most feasible and most effective treatment of the surface to provide reliable bond must be defined. Several procedures for cleaning and texturing the surface of the existing pavement are available, but it is not known if these are equally effective, or more importantly, equally cost-effective for promoting reliable bond.

Among the areas of special study which could provide improved bond at a lower cost are less labor-intensive methods for grout application, such as pressure spraying a neat cement grout or even complete elimination of the grout. This latter approach may be particularly suitable if a very high cement factor concrete is used. There are also some conflicting data and opinions on whether the surface must be complete dry or whether it can be damp or wet when the grout is applied. If a dry surface is absolutely required, costly construction delays may occur after rainstorms.

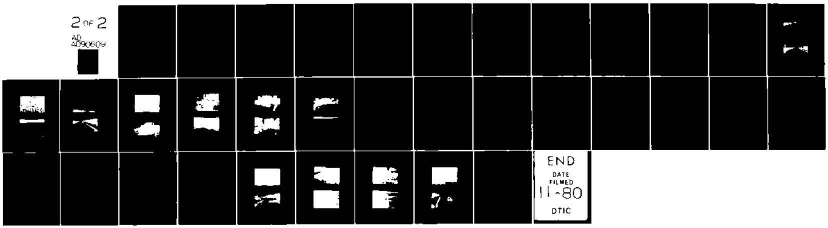
Questions have also been raised regarding the effect of drying winds and high temperatures on the grout after application to the pavement. That is, under severe drying conditions, how long a time can be tolerated between application of the grout and placement of the concrete overlay?

3. Different methods of surface preparation should also be evaluated. It was shown that nearly all types of milling or surface texturing which remove a layer of concrete from the pavement will provide good bond. Some milling procedures do, however, cause distress in the joints of the existing slab. Sandblasting has also proven to be effective in cleaning the slab surface, but does not remove a significant thickness of concrete and so may not remove some oils and paints which have penetrated the concrete surface. Sandblasting also caused some dusting which would make it environmentally unacceptable, especially in urban areas. A combination of water and sandblasting has been suggested as a more effective procedure for surface removal and texturing and with less environmental problems than sandblasting alone. This procedure should be evaluated as it appears to have great potential, at least for some specialized applications.

4. Studies should be undertaken to determine the level of deterioration of joints and cracks or other surface deterioration such as D-lined cracking in the existing pavement, which can be tolerated, and the appropriate rehabilitation procedures prior to overlaying. This is a long-range study as it includes evaluation of pavement performance over many years. This study can be initiated by carefully following the performance of overlaid pavements with different levels of deterioration and different treatments in bonded overlay projects.

Most chapters of the report contain a section on unresolved problems which provide more detailed summaries of unresolved problems.

AD-A090 609 DARTER AND BARENBERG CONSULTING ENGINEERS URBANA IL F/G 13/2
BONDED CONCRETE OVERLAYS: CONSTRUCTION AND PERFORMANCE.(U)
SEP 80 M I DARTER, E J BARENBERG DACA39-79-M-0124
UNCLASSIFIED WES/MP/GL-80-11 NL



BIBLIOGRAPHY

1. Schroder, C. J., Britson, R. A., and Bergren, J. V., "Bonded, Thin-Lift Non-Reinforced Portland Cement Concrete Resurfacing," Iowa Department of Transportation, Division of Highways, May 1977.

2. Johnson, M. L., "Bonded, Thin-Lift Portland Cement Concrete Resurfacing," Report on Project HR191, Clayton County and Iowa Highway Research Board, September 1977.

3. Knutson, M. J., "An Evaluation of Bonded, Thin-Lift, Non-Reinforced Portland Cement Concrete Resurfacing and Patching," Paper presented at 62nd Annual Meeting AASHTO, Birmingham, Alabama, November 1976.

4. Lankard, D. R., and Walker, A. J., "Pavement Applications for Steel Fibrous Concrete," Transportation Engineering Journal, February 1975.

5. Johnson, M., "Iowa County's 3-R Concrete Project Tries New Methods, Evaluates Old Ones," Rural and Urban Roads, August 1978.

6. Norling, L. T., "Concrete Overlays and Resurfacing," A Status Report, Portland Cement Association.

7. Felt, E. J., "Resurfacing and Patching Concrete Pavement with Bonded Concrete," Proceedings, Highway Research Board, Vol. 35, 1956.

8. Gillette, R. W., "A 10-Year Report on Performance of Bonded Concrete Resurfacings," Highway Research Record No. 94, Transportation Research Board, 1965.

9. Westall, W. G., "Bonded Resurfacing and Repairs of Concrete Pavement," Bulletin 266, Highway Research Board, 1960.

10. Westall, W. G., "Bonding Thin Concrete to Old," Civil Engineering, Vol. 28, No. 6, 1958.

11. Portland Cement Association, "1977 Condition Survey Concrete Resurfacing, Plain and Reinforced Concrete," 1978.

12. "Repairing it to Last; Bonded Concrete Cures Ailing Bridge Decks," Rural and Urban Roads, May 1974.

13. "Four Concrete Overlay Methods Tested for Sheet Resurfacing Modern Concrete," Modern Concrete, February 1977.

14. Purinton, J. B., Jr., "A New Look at Thin Bonded Concrete Overlays," Roads and Streets, February 1962.

15. Hughes, H. W., "Thin Concrete Topping Restores Old Pavement," Proceedings, ACI, April 1951.

16. Farlow, J. F. Jr., "Utilizing Epoxy Resin Adhesives," Rural Roads, February 1961.

17. "Polysulfide Mortars Used for Rapid Concrete Paving Repairs," Roads and Road Construction, February 1961.

18. Lemcoe, M. M., and Mahla, C. H., "Prestressed Overlay Slab for San Antonio Airport," Journal, ACI, July 1959.

19. Lockhardt, W. F., "Vacuum Concrete," Proceedings, ACI, Vol. 34, Jan.-Feb. 1938.

20. Gauld, V. G., "Summarized Committee Report 1948-1960; Salvaging Old Pavements by Resurfacing."

21. "Bonded Overlay Gives New Life to Old Runway," Engineering News Record, November 1978.

22. Barenberg, E. J., and Ratterree, B. L., "Fully Bonded Concrete Overlay for an Airport Runway," Proceedings, Int. Air Trans. Conference, New Orleans, LA, 1979.

23. Martin, R., "Design and Construction of Concrete Resurfacing of Concrete Pavements," Special Report 116, Transportation Research Board, 1971.

24. Highway Research Board, "Salvaging Old Pavements by Resurfacing, Part I, Rigid-Type Overlays," Bibliography No. 21, 1957.

25. Highway Research Board, "Salvaging Old Pavements by Resurfacing, Rigid-Type Overlays," Supplement, Bibliography No. 21, 1963.

26. Purinton, J. B., Jr., "Thin Concrete Overlay for Runway," Military Engineer, No. 350, Nov.-Dec. 1960.

27. Felt, E. J., "Repair of Concrete Pavement," Proceedings, ACI, Vol. 57, No. 2, 1960.

28. U. S. Army Engineer District, Nashville, "Report on Thin Bonded Concrete Overlay Pavement for Parking Hardstands," Campbell Air Force Base, Kentucky, U. S. Army Corps of Engineers, Nashville, Tennessee, 1957.

29. Hutchinson, R. L. and Wathen, T. R., "Strengthening Today's Pavements for Tommorrow's Aircraft," Paper presented at Annual Convention, ASCE, 1961.

30. Gillette, R. W., "Performance of Bonded Concrete Overlays," Proceedings, ACI, Vol. 60, No. 1, 1963.

31. Adams, J. B., "Overlay for Concrete Pavement Repair," Military Engineer, No. 362, 1962

32. U. S. Army Corps of Engineers, "Condition Survey Report - Bunker Hill Air Force Base, Indiana," Rigid Pavement Lab., ORDL, 1962.

33. U. S. Army Corps of Engineers, "Condition Survey Report of Thin Bonded Overlay, Standiford Field, Louisville, Kentucky," Rigid Pavement Lab., ORDL 1962.

34. U. S. Army Corps of Engineers, "Condition Survey Report, Randolph Air Force Base, Texas," Rigid Pavement Lab., ORDL, 1962.

35. U. S. Army Corps of Engineers, "Condition Survey Report of Thin Bonded Overlay, Fort Campbell Army Airfield, Kentucky," Rigid Pavement Lab., ORDL, 1961.

36. U. S. Army Corps of Engineers, "Condition Survey Report, Selfridge Air Force Base, Michigan," Rigid Pavement Lab., ORDL, 1963.

37. Carlson, R. W., "Drying Shrinkage of Concrete as Affected by Many Factors," Proceedings, ASTM, Vol. 38, Part II, 1938.

38. Newlon, H. H., Jr., "Relationship Between Properties of Hardened Concrete and Bridge Deck Performance," Report VHTRC 77-WP41, Virginia Highway and Transportation Research Council, 1976.

39. Sprinkel, M. M., "Effective Field Use of Superplasticized Concrete," Report VHTRC 77-WP21, Virginia Highway and Transportation Council, 1977.

40. Sprinkel, M. M.,"Super-Water Reduced Concrete Pavements and Bridge Deck Overlays," Proceedings, Symposium, Superplasticizers in Concrete, Vol. 1, Ottawa, Canada, 1978.

41. Crawford, Murphy, and Tilly, Inc., Consulting Engineers, "Specifications for Overlay, Mark and Groove Runway 4122, University of Illinois Willard Airport," 1978.

42. Portland Cement Association, "Pavement Resurfaced with Concrete," 1934.

43. Portland Cement Association, "Resurface Old Pavements with Concrete," R-35, 1955.

44. Juckel, P. and Tracy, R. G., "Low Slump Concrete Overlay of a Continuously Reinforced Concrete Pavement," Minnesota DOT, 1979.

45. Texas Transportation Institute, "Bond and Durability of Concrete and Resinous Overlays," Research Report, Texas A & M University, 1974.

46. University of Illinois, "Determination of Optimum Maintenance Procedures for CRCP," Illinois Cooperative Highway Research Project IHR-901, 1976-1980 (M. I. Darter, Principal Investigator).

47. Withey, M. D., "Bond of Vibrated Concrete," Proceedings, Highway Research Board, Vol. 16, 1936.

48. Waters, T., "A Study of the Tensile Strength of Concrete across Construction Joints," Magazine of Concrete Research, England, Vol. 6, Dec. 1954, Highway Research Abstracts, April 1955.

49. "New York Tests First Cement Concrete Overlay," Engineering News Record, August 30, 1979.

50. Betterton, R. H. and Knutson, M. J., "A Five Year Performance Summary of Fibrous PC Concrete Overlay Research in Green Co., Iowa," Final Report, Office of County Engineers, Green Co., Iowa, December 1978.

Appendix A

IOWA DEPARTMENT OF TRANSPORTATION

Ames, Iowa

Supplemental Specification

for

PORTLAND CEMENT CONCRETE RESURFACING
September 14, 1976

THE STANDARD SPECIFICATIONS, SERIES OF 1972, ARE AMENDED BY THE FOLLOWING ADDITIONS. THESE ARE SUPPLEMENTAL SPECIFICATIONS AND SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

796.01 DESCRIPTION. Resurfacing of concrete pavements shall consist of removing concrete from the existing surface, replacing and overlaying with new concrete, and other necessary work as shown on the plans or as specified. The work shall be done according to the Standard Specifications and this specification. Unless otherwise provided on the plans, resurfacing shall accomplish a raise of the existing roadway surface and shall cover the entire pavement surface.

796.02 MATERIALS. All materials shall meet the requirements for the respective items in Part IV of the Standard Specifications, with the following exceptions:

A. Cement. Article 4101 shall apply. The use of Type III (high early strength) cement will not be permitted.

B. Aggregate. Sections 4110 and 4115 shall apply with the exception that the coarse aggregate shall meet the following gradation requirements and shall be a Class 2 crushed stone produced by crushing ledge rock. It shall contain no chert and shall have an absorption not exceeding 3.0 percent.

Sieve Size	Percent Passing Min.	Max.
3/4"	100	
1/2"	97	100
3/8"	40	90
No. 4	5	30
No. 200	0	1.5

C. Concrete shall meet the following requirements.

Basic Absolute Volumes per Unit Volume of Concrete:

	Mix A	Mix B
Coarse Aggregate	0.306731	0.343955
Fine Aggregate	.306731	.343955
Air	.060000	.060000
Water	.170970	.133760
Cement	.155568	.118330

Approximate Quantities of Materials Per Cubic Yard of Concrete:

	Mix A	Mix B
Coarse Aggregate	1,370 lbs.	1,536 lbs.
Fine Aggregate	1,370 lbs.	1,536 lbs.
Cement	823 lbs.	626 lbs.
Water	288 lbs.	225 lbs.

These quantities are based on the following assumptions:

Specific gravity of cement	3.14
Specific gravity of coarse and fine aggregate	2.65
Weight of one cu. ft. of water	62.4 lbs.

Water-cement ratio, 0.35 lb./lb. for Mix A and 0.36 lb./lb. for Mix B.
The maximum water-cement ratio, including free water in the aggregate, shall be 0.39 lb./lb for Mix A and 0.40 lb./lb. for Mix B.
A super water-reducing admixture for improving workability will be required. This admixture shall be approved by the engineer.
The slump, measured in accordance with AASHTO T 119, shall be a maximum of 2 1/2 inches.
The intended air entrainment of the finished concrete is 6 percent, but the air content of fresh, unvibrated concrete at the time of placement, as determined by AASHTO T 152, shall be 6.5 percent, with a maximum variation of plus or minus 1.5 percent.

D. Grout for bonding new concrete to previously placed concrete shall consist by equal parts of weight of portland cement and concrete sand, mixed with sufficient water to form a stiff slurry. The consistency of this slurry shall be such that it can be applied with a stiff brush or broom to the old concrete in a thin, even coating that will not run or puddle in low spots.

796.03 EQUIPMENT. Equipment used shall be subject to approval of the engineer and shall comply with the following:

A. Surface Preparation Equipment shall be of the following types:

1. Sawing Equipment shall be capable of sawing concrete to the specified depth.
2. Sand-Blasting Equipment shall be capable of removing rust, oil, and concrete laitance from the existing surface on the pavement.
3. Scarifying Equipment shall be a power-operated, mechanical scarifier capable of uniformly scarifying or removing the old surface to depths required in a satisfactory manner. Other types of removal devices may be used if their operation is suitable and if they can be demonstrated to the satisfaction of the engineer.

B. Proportioning and Mixing Equipment shall meet requirements of 2001.20 and 2001.21. Sufficient mixing capacity or mixers shall be provided to permit the intended pour to be placed without interruption.

C. Placing and Finishing Equipment. An approved machine complying with requirements of 2301.07B shall be used. The machine shall be inspected and approved before work is started on each project.

796.04 PREPARATION OF SURFACE. The entire, existing concrete pavement surface shall be uniformly scarified or prepared to a depth of 1/4 inch, except over areas of partial-depth or full-depth repair where the 1/4-inch removal may be coincidental with operations for repair removal.

The thickness of all new concrete above the prepared surface shall be as specified on the plans.

Prior to applying grout in preparation for placement of new concrete, the surface shall be sandblasted followed by an air blast. The sandblast shall be of such an extent to remove all dirt, oil, and other foreign material, as well as any unsound concrete or laitance from the surface and edges against which new concrete is to be placed. It is desired that the surface be roughened by the sandblast to provide satisfactory bond with the surfacing concrete. It is not intended or desired that existing concrete, prepared for resurfacing, be presaturated before grout and new concrete is placed. The prepared surface shall be dry to allow some absorption of the grout.

796.05 PROPORTIONING AND MIXING OF CONCRETE MATERIALS. The applicable provisions of 2301.16 shall apply with the following exceptions and additional provisions:

A. The super water-reducing admixture for improved workability shall be mixed and incorporated in the concrete mixture in accordance with the manufacturer's recommendations and the engineer's instructions.

796.06 PLACING AND FINISHING CONCRETE. The contractor shall take every reasonable precaution to secure a smooth-riding surface. Prior to placement operations, he shall review his equipment, procedures, personnel, and previous results with the engineer, and the inspection procedures will be reviewed to assure coordination. Precautions shall include the following:

Assurance that concrete can be produced and placed within the specified limits, continuously and with uniformity.

After finishing, the contractor shall check the surface with a 10-foot light straightedge; causes for irregularities exceeding 1/8 inch should be eliminated, and corrections should be made, if practical.

At transverse and longitudinal joints, the surface course previously placed shall be sawn to a straight and vertical edge before the adjacent surface course is placed.

After the surface has been cleaned and immediately before placing concrete, a thin coating of bonding grout shall be scrubbed into the dry, prepared surface. Care shall be exercised to insure that all parts receive a thorough, even coating and that no excess grout is permitted to collect in pockets. The rate of progress in applying grout shall be limited so that the grout does not become dry before it is covered with new concrete.

Placement of the concrete shall be a continuous operation throughout the pour, including patch areas. Internal, hand vibration will be required at full-depth patches and may be required at partial-depth patches. Hand finishing with a wood float may be required for producing a tight, uniform surface.

When a tight, uniform surface has been achieved, the surface shall be given a suitable texture with a wire broom or comb having a single row of tines. The desired texture is transverse grooving which may vary from 1/16-inch width at 1/2-inch centers to 3/16-inch width at 3/4-inch centers, and the groove depth should be 1/8 inch to 3/16 inch. This operation shall be done at such time and in such manner that the desired texture will be achieved while minimizing displacement of the larger aggregate particles. The texture need not extend into the areas within approximately 6 inches of the outside edge.

After the surface has been textured, the surface shall be promptly covered with a single layer of clean, wet burlap or shall be cured in accordance with 2301.22A except that liquid curing compounds shall be applied at twice the minimum specified rate. The locations for wet burlap curing will be shown on the plans.

It is intended that the surface receive a wet burlap or liquid membrane cure for at least 72 hours. For the first 24 hours, the burlap shall be kept continuously wet by means of an automatic sprinkling or wetting system. After 24 hours, the contractor may cover the wet burlap with a layer of 4-mil polyethylene film for a minimum of 48 hours in lieu of using a sprinkling or wetting system.

796.07 LIMITATIONS OF OPERATIONS. If traffic is to be maintained during the construction period of this contract, it will be noted on the plans. The contractor shall provide such traffic contols as required by the plans and specifications.

No traffic shall be permitted on finished resurfacing course until 72 hours after placement. At temperatures below 55 degrees F., the engineer may require a longer waiting time.

No concrete shall be placed when the air or pavement temperature is below 40 degrees F.

796.08 METHOD OF MEASUREMENT. The quantity of the various items of work involved in the construction of portland cement concrete resurfacing will be measured by the engineer in accordance with the following provisions:

A. Portland Cement Concrete Resurfacing. The area of resurfacing constructed of the mix proportions and thickness specified will be computed in square yards from surface measure longitudinally and the nominal plan width.

B. Surface Preparation. The length of pavement prepared in accordance with the specifications will be measured in stations along the centerline of the pavement.

C. Partial-Depth Repair. The volume of concrete for partial depth repair of transverse joints will be computed in cubic yards, to the nearest 0.1, from measurements of the repair locations. Partial-depth repair will be considered to start 1/4 inch below the existing pavement surface, but this shall not preclude removal coincidental with preparation for resurfacing.

D. Full-Depth Patches. Patches involving full-depth removal of old pavement and its replacement with portland cement concrete will be computed in square yards from measurements of the areas of concrete removed, except that each patch which is less than 18 square feet in area will be counted as 2.0 square yards.

796.09 BASIS OF PAYMENT. For the performance of acceptable work, measured as provided above, the contractor will be paid the contract unit price in accordance with the following provisions:

A. Portland Cement Concrete Resurfacing. For the number of square yards of portland cement concrete resurfacing constructed, the contractor will be paid the contract price per square yard. This shall be full compensation for furnishing all material, equipment, and labor necessary to complete this work, including the placement of the grout, in accordance with the plans and these specifications.

B. Surface Preparation. For the stations of pavement prepared as specified herein, the contractor will be paid the contract price per station. This shall be full compensation for removing a nominal 1/4 inch of pavement, stockpiling the material, sandblasting, air blasting, and placing the material removed on the shoulders adjacent to the resurfacing.

C. Partial-Depth Repair. Partial-depth repair will be paid for at the contract price per cubic yard. This price shall be full compensation for the removal and stockpiling of the old pavement.

D. Full-Depth Patches. For the number of square yards of full-depth patches placed, the contractor will be paid the contract price per square yard. This price shall be full compensation for removal and disposal of the old pavement and for all materials and other items involved in construction of such patches.

APPENDIX B

RECENT BONDED CONCRETE OVERLAY PROJECTS

New York Project - 1979

A thin-bonded concrete overlay project currently under construction in New York (Ref. 49)* involves removing and replacing a 2- to 2-1/4-in. thickness of badly spalled concrete pavement. A cold planer was used to mill out the spalled areas in three passes. A sandblasting crew followed directly behind the cold planer for two purposes: "dislodging loose material and adding to the roughness of the surface" (Ref. 49). The surface was then airblasted to remove all loose particles. Polyethylene sheeting was placed over the blown-out area until the area was paved. A 1:1 sand-cement stiff slurry was hand-broomed into the planed surface. A 2-1/2- to 3-1/2-in. slurry concrete was placed and vibrated on the prepared surface.

* References cited in this Appendix are listed by number in the Bibliography at the end of the main text.

Iowa I-80 Bonded Concrete Overlay

The Iowa Department of Transportation has recently overlaid a segment of I-80 near Avoca, Iowa with a thin-bonded PCC overlay. The specific project consisted of preparing the surface by cold milling and sandblasting and placing a nominal 3-inch bonded PCC overlay on approximately 4-1/2 miles of two-lane CRC pavement. Details of the project provided at the open house held on September 25, 1979 and photographs of the construction operations in progress on that date are provided in this report.

The existing pavement for the major portion of the project was an 8-inch-thick continuously reinforced concrete (CRC) slab on a 4-inch-thick granular subbase constructed in 1966. Approximately 2100 feet at the easternmost end of the project consisted of a 10-inch jointed concrete pavement with dowelled joints at a spacing of 76-1/2 feet and mesh reinforcing between joints. Four (4) inches of granular subbase was used directly under the slab. This eastern portion of the project was constructed in 1965.

Mix proportions for the concrete used in both parts of the original pavement contained 626 pounds of portland cement and equal parts of fine and coarse aggregate. The coarse aggregate was a crushed limestone and the sand was a natural concrete sand.

This particular roadway was selected because its condition was representative of many miles of D-crack deterioration on CRCP in Iowa. Also, it provided an opportunity to evaluate a thin-bonded PCC overlay under exactly the same traffic and weather conditions on mesh-dowel plain pavements as well as CRC pavements. The present traffic count for this pavement is 12,780 vehicles per day with approximately 25 percent trucks.

Specifications for this rehabilitation are attached hereto in the form of Iowa DOT Supplemental Specifications for PCC Pavement Repair (3R Projects) and Special Provisions for Portland Cement Concrete Resurfacing on I-80.

The essential steps in this project, as detailed in the specifications attached, consisted of milling the existing concrete surface to a depth of approximately 1/4 inch, or to sound concrete, sandblasting, power sweeping the milled surface, applying a neat cement grout and then applying a three-inch PCC overlay with a slip-form paver. The final overlay surface was textured and cured as any normal concrete pavement except that the membrane-forming curing compound was applied at 1-1/2 times the normal rate in two applications.

The only unique aspects of this project compared to those described earlier in the report are the use of a spray-applied neat cement grout and the use of sand at truck turnaround locations on the prepared surface to prevent rubber deposition on the surface.

The photographs included with this report and the detailed captions show the essential steps in the construction procedure for this project. Figure B-1 shows the general condition of the pavement in the westbound traffic lane of I-80, which was not being overlaid at this time. The resurfaced pavement in the eastbound lane was more extensively D-cracked than the non-overlayed westbound lane (Figure B-1). Figures B-2 and B-3 show the pavement surface after Roto-Milling and sandblasting. Note the deeper milling along the centerline of the pavement. This was achieved by first milling two lanes each 9 feet wide along the pavement edges and then milling the centerline with 30-inch passes with a Galion milling machine.
Figures B-4 and B-5 show a transverse joint and crack in the pavement after milling and sandblasting. Note especially in Figure B-5 the absence of spalling along the tight crack. Figure B-6 shows a major longitudinal

crack after milling and sandblasting, and Figure B-7 an area which had been milled down to the longitudinal steel to effect a surface patch in an area of deteriorated concrete.

Equipment used for sandblasting the pavement surface after milling is shown in Figures B-8 and B-9.

The sand cover used to protect the prepared surface is shown in Figure B-10.

Application of the water-cement grout by pressure spraying just in front of the paver is shown in Figure B-11. Note in Figure B-12 how the truck backing over the grouted area has not picked up any of the grout on the tires, even though only a few minutes had lapsed between application of the grout and the arrival of the truck.

The final pavement overlay is shown in Figures B-13 and B-14.

Figure B-1. General Condition of I-80 Shown in the Westbound Lane Which Was Not Being Overlaid at This Time.

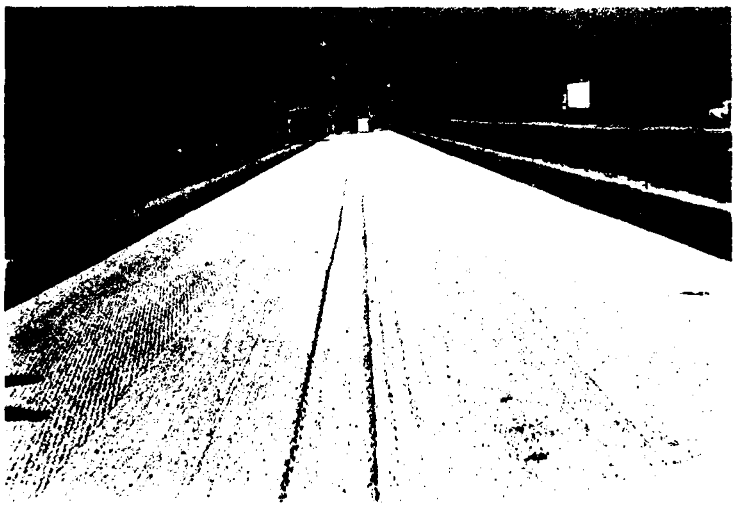


Figure B-2. Roto-Milled and Sandblasted Surface Showing the General Condition of the Prepared Surface. Note the Deeper Milling Along the Centerline.

Figure B-3. Closeup of the Prepared Surface Showing Surface Texture After Melting and Sandblasting.

Figure B-4. Side View of Milled and Sandblasted Surface Showing a Transverse Joint and Crack.

Figure B-5. Closeup of the Transverse Crack Showing the Final Surface Condition. Note the Absense of Spalling Along the Crack.

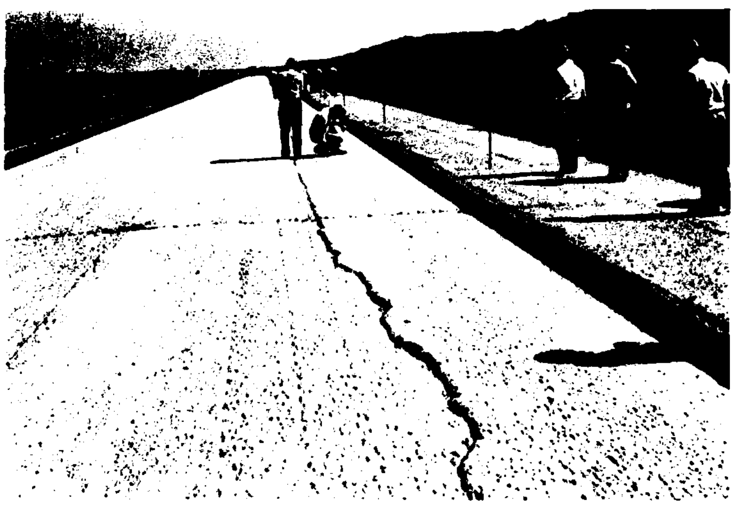


Figure B-6. Major Longitudinal Crack After Milling and Sandblasting. Note the Major Spalled Area.

Figure B-7. Area of Deep Surface Removal Down to the Longitudinal Steel.

Figure B-8. Overview of Sandblasting Equipment Used on the Project.

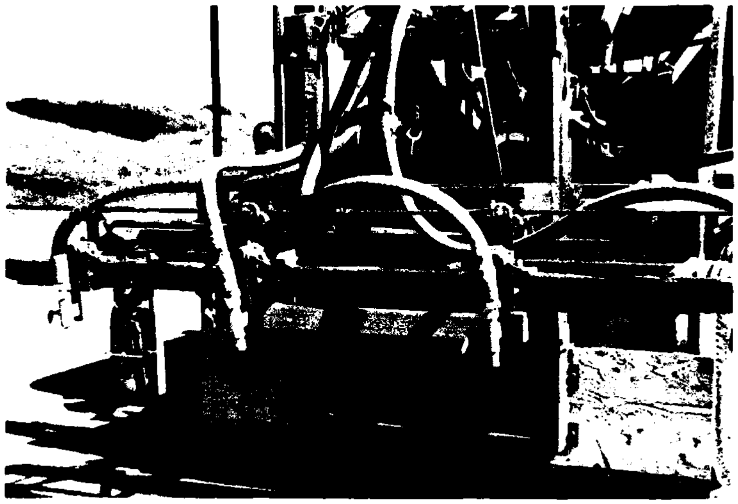


Figure B-9. Closeup of the Blasting Nozzles on the Sandblasting Equipment Used on the Project.

Figure B-10. Sand Cover Placed at Turnaround Locations on the Pavement to Prevent Rubber Buildup on the Prepared Surface.

Figure B-11. Spraying of the Neat Cement Grout in Front of the Paver.

Figure B-12. Front View of Paver With Concrete Truck Rear Tires in Grouted Area. Note the Absence of Any Grout Pickup on the Rear Tires.

Figure B-13. Pavement Overlay Just Behind the Slip-Form Paver Before Hand-Finishing, Texturing, and Application of Curing Compound.

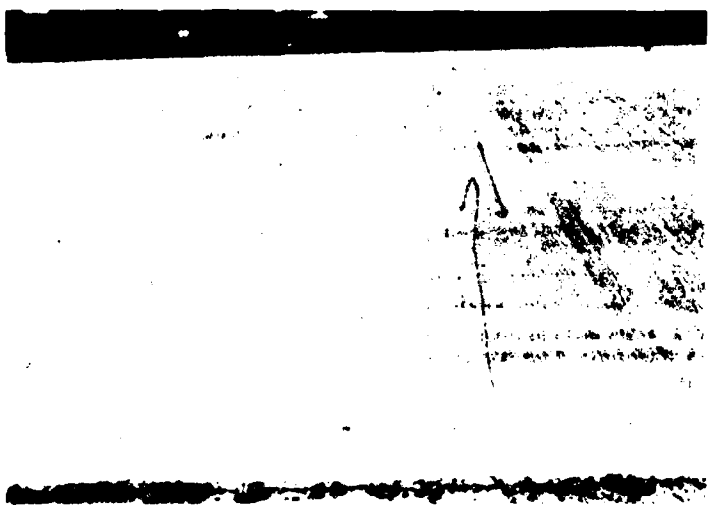


Figure B-14. Final Overlay After Texturing and Application of Curing Compound.

Specification 831

IOWA DEPARTMENT OF TRANSPORTATION

Ames, Iowa

SUPPLEMENTAL SPECIFICATION

for

PCC PAVEMENT REPAIR
(3R Projects)

June 20, 1978

THE STANDARD SPECIFICATIONS, SERIES OF 1977, ARE AMENDED BY THE FOLLOWING ADDITIONS. THESE ARE SUPPLEMENTAL SPECIFICATIONS AND SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

831.01 DESCRIPTION. Restoration of concrete pavements shall consist of partial-depth patches, full-depth patches, installing pressure-relief joints, and other necessary work as shown on the plans or as specified. The work shall be done according to the Standard Specifications and this specification.

831.02 MATERIALS. All materials shall meet requirements for the respective items in Part IV of the Standard Specifications, with the following exceptions:

A. Cement. Article 4101 shall apply.

B. Aggregate. Sections 4110 and 4115 shall apply except that coarse aggregate shall be of a Class 2 durability.

C. Concrete. Concrete for both partial- and full-depth patches, on a closed road section, shall be Class M, as described in 2301.04E.

The slump, measured in accordance with AASHTO T 119, shall be 1-1/2 inches, plus or minus 1/2 inch.

The entrained air content of the fresh, unvibrated concrete, at the time of placement, as determined by AASHTO T 152, shall be 6.5 percent, with a tolerance of plus or minus 1.5 percent. An approved water reducing agent will be required with all Class M concrete, in accordance with I.M. 403.

In areas where the roadway must be opened to traffic during the nighttime, the concrete mixture used for both partial- and full-depth patches shall be as specified in 2212.02B.

D. Grout for bonding new concrete to previously placed concrete shall consist of equal parts by weight of portland cement and concrete sand, mixed with sufficient water to form a stiff slurry. The consistency of this slurry shall be such that it can be applied with a stiff brush or broom to the old concrete in a thin, even coating that will not run or puddle in low spots. The grout shall be agitated prior to and during its use. The cement-to-water contact time of the grout shall not exceed 90 minutes before it is placed.

An equivalent grout of portland cement and water, applied by pressure spray, may be substituted with approval of the engineer.

831.03 EQUIPMENT. Equipment used shall be subject to approval of the engineer and shall comply with the following:

A. Surface Preparation Equipment shall be of the following types:

1. Sawing Equipment shall be capable of sawing concrete to the specified depth.
2. Scarifying Equipment shall be a power-operated, mechanical scarifier capable of uniformly scarifying or removing the old surface to depths required in a satisfactory manner. Other types of removal devices may be used if their operation is suitable and if they can be demonstrated to the satisfaction of the engineer.

B. Volumetric proportioning and continuous-mixing equipment, meeting requirements of 2001.20 and 2413.03, may be approved by the engineer. The written approval must be obtained from the engineer prior to the delivery of any concrete, mixed with this equipment, to the project. It is intended and desired that volumetric proportioning and continuous-mixing equipment be used for all repair areas that must be open to traffic during hours of darkness.

831.04 PREPARATION OF REPAIR AREAS. Full-depth patch areas shall be prepared in accordance with 2212.04B, except as modified by this specification and as shown on the plans. Wheel saws may be used for removal in areas of full-depth patches, provided the limits of the patch area are sawn to a depth of 1-1/2 inches using diamond or carborundum blades.

Partial-depth patches shall be constructed at locations shown on the plans, or as directed by the engineer. The deteriorated concrete shall be removed to a nominal width and depth as indicated on the plans, normally to sound concrete. It is intended and desired that the edges of the partial-depth patch areas be reasonably straight and vertical. Near vertical edges, resulting from using self-propelled milling machines, will be considered acceptable.

Full-depth patches shall be made at locations shown on the plans or designated by the engineer. If the base or subgrade is disturbed in the removal operations or if additional fill material is added, the full-depth patch area shall be compacted prior to concrete placement.

When removed material is to be salvaged, it will be so indicated on the plans. When salvage is not indicated on the plans, removed material shall be disposed of by the contractor in accord with 1104.08.

Prior to applying grout in preparation for placement of new concrete, the entire surface of each partial-depth patch area shall be cleaned with an air blast. If the air blast will not sufficiently clean the repair area, sand blasting or water blasting may be required, as directed by the engineer.

It is not intended or desired that the existing concrete, prepared for partial-depth patches, be presaturated before grout and new concrete are placed. The prepared surface shall be dry to allow some absorption of the grout.

Forms shall be used to provide straight and neat lines on the ends of both the partial- and full-depth patches. Any damage to the existi shoulders caused by preparation of the repair areas, shall be repaired

by the contractor at no additional cost to the contracting authority. Bituminous materials used for shoulder repair shall be similar to that used in the original construction, or as approved by the engineer.

Pressure-relief joints shall be constructed in accordance with the plans.

831.05 PLACING AND FINISHING CONCRETE. After the surface of the partial-depth patch areas has been cleaned and immediately before placing concrete, a thin coating of bonding grout shall be scrubbed into the dry, prepared surface. Care shall be exercised to insure that all parts receive a thorough, even coating and that no excess grout is permitted to collect in pockets. The rate of progress in applying grout shall be limited so that the grout does not become dry before it is covered with new concrete.

A vibrating screed shall be required to provide a tight, uniform surface on the repair areas. The surface of the repair areas shall be given a transverse broom or Astro-grass texture.

The edges and bottom of the full-depth patch areas shall be uniformly moist before concrete is placed.

Joints in the partial-depth patch areas over the existing transverse joints shall be scored to a depth of 1/4 the repair thickness, but not less than 1-1/2 inches, and finished with an edging tool. Inserting a parting strip, to the same minimum depth, may be approved by the engineer.

After the surface of the patch areas has been textured, the surface shall be cured in accordance with 2301.22.

831.06 LIMITATIONS OF OPERATIONS. If traffic is to be maintained during the construction period of this contract, it will be noted on the plans. The contractor shall provide such traffic controls as required by the plans and specifications.

No traffic shall be permitted on the repair areas utilizing Class M concrete until 72 hours after placement. Concrete mixed with calcium chloride, in accordance with 2212.02B, shall not be opened to traffic for a minimum of 4 hours after the application of the cure. At temperatures below 55 degrees F, the engineer may require a longer waiting time. No concrete shall be placed when the air or pavement temperature is below 40 degrees F.

831.07 METHOD OF MEASUREMENT. The quantity of the various items of work involved in the construction of portland cement concrete repair will be measured by the engineer in accordance with the following provisions:

A. Partial-Depth Patches. The areas of partial-depth patches will be computed in square yards from measurements of the repair locations.

B. Full-Depth Patches. Patches involving full-depth removal of old pavement and its replacement with portland cement concrete will be computed in square yards from measurements of the area of concrete removed, except that each patch which is less than 18 square feet in area will be counted as 2.0 square yards.

831.08 BASIS OF PAYMENT. For the performance of acceptable work, measured as provided above, the contractor will be paid the contract unit price in accordance with the following provisions:

A. Partial-Depth Patches. Partial-depth patches will be paid for at the contract price per square yard. This price shall be full compensation for the removal and disposal of the old pavement, furnishing, placing, finishing, and curing of the concrete, repair of the shoulder, and traffic control.

B. Full-Depth Patches. For the number of square yards of full-depth patches placed, the contractor shall be paid the contract price per square yard. Should a full-depth patch be ordered by the engineer at an area prepared for partial-depth repair, the contractor shall be paid one-half the contract price per square yard for partial-depth patch, in addition to the contract price per square yard for full-depth patch.

This price shall be full compensation for the removal and disposal of the old pavement, furnishing, placing, finishing, and curing of the concrete, repair of the shoulder, and traffic control.

The plans will detail the measurement and payment for pressure-relief joints and the work to be included in such payment.

IOWA DEPARTMENT OF TRANSPORTATION
Ames, Iowa

Special Provisions
for

PORTLAND CEMENT CONCRETE RESURFACING ON I-80

Pottawattamie County Project I-EACIR-80-1(126)34--OC-78

June 19, 1979

THE STANDARD SPECIFICATIONS, SERIES OF 1977, ARE AMENDED BY THE FOLLOWING ADDITIONS. THESE ARE SPECIAL PROVISIONS AND SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

259.01 DESCRIPTION. Resurfacing of concrete pavement shall consist of cleaning and preparation of the existing surface, overlaying with new, bonded concrete, and other necessary work as shown on the plans or as specified. The work shall be done according to the Standard Specifications and this specification. Unless otherwise provided on the plans, resurfacing shall accomplish a raise of the existing roadway and shall cover the entire pavement surface.

259.02 MATERIALS. All materials shall meet the requirements for the respective items in Part IV of the Standard Specifications, with the following exceptions:

A. Cement. Article 4101 shall apply. The use of Type III (high early strength) cement will not be permitted.

B. Aggregate. Sections 4110 and 4115 shall apply, and the coarse aggregate shall be a Class 2 durability, crushed limestone meeting the number 3 or 5 gradation requirements of Section 4109.

C. Concrete. Mix No. C-4WR, as specified in 2301.04 shall be used for resurfacing and may be used in repair areas. Class M concrete shall be used for full-depth or partial-depth repairs that will be subject to traffic prior to resurfacing.

D. Grout for bonding new concrete to previously placed concrete shall consist of equal parts by weight of portland cement and concrete sand, mixed with sufficient water to form a stiff slurry. The consistency of this slurry shall be such that it can be applied with a stiff brush or broom to the old concrete in a thin, even coating that will not run or puddle in low spots. The grout shall be agitated prior to and during its use. The cement-to-water contact time of the grout shall not exceed ninety (90) minutes before it is placed. An equivalent grout of portland cement and water, applied by pressure spray, may be substituted with approval of the engineer.

259.03 EQUIPMENT. Equipment used shall be subject to approval of the engineer and shall comply with the following:

A. Surface Preparation Equipment shall be of the following types:

1. Sawing Equipment shall be capable of sawing concrete to the specified depth.

2. Sand-Blasting Equipment shall be capable of removing rust, oil and concrete laitance from the existing surface of the pavement

3. Scarifying Equipment shall be a power-operated, mechanical scarifier capable of uniformly scarifying or removing the old surface to depths required in a satisfactory manner. Other types of removal devices may be used if their operation is suitable and if they can be demonstrated to the satisfaction of the engineer.

B. Proportioning and Mixing Equipment shall meet requirements of 2001.20 and 2001.21. Sufficient mixing capacity or mixers shall be provided to permit the intended pour to be placed without interruption.

C. Placing and Finishing Equipment. An approved machine meeting requirements of 2301.07B shall be used. The machine shall be inspected and approved before work is started on each project.

The Contractor shall construct the pavement in a manner and with a system that will provide a smooth-riding surface. The placing equipment shall be either controlled to the proper elevation by stringline or operated on a pad line that is constructed to a controlled, proper elevation.

259.04 PREPARATION OF SURFACE. The entire, existing concrete pavement surface shall be scarified, followed by sand blasting. Sand blast shall be of such an extent as to remove all dirt, oil, and other foreign material, as well as any laitance or loose concrete from the surface and edges against which new concrete is to be placed. Where scarification is designated, the existing surface shall be scarified to a nominal depth of 1/4 inch.

In areas of sufficient surface deterioration, the scarification shall be to a nominal depth of 1 inch. These areas will be shown on the plans, or as designated by the engineer. The locations requiring one-inch scarification will normally be at least one travel lane (12 feet) in width. When neither lane is designated for one-lane scarification and the centerline is so designated, a nominal width of 30 inches is intended.

Partial-depth repair of transverse joints shall be done at locations shown on the plans, or as directed by the engineer. The deteriorated concrete shall be removed to a nominal width and depth as indicated on the plans, normally to sound concrete or to the top of the reinforcing steel. Full-depth patches shall be made at locations shown on the plans or designated by the engineer. The partial-depth repairs and full-depth patches shall be done in accordance with Supplemental Specification 831 except as modified by this specification.

Full-depth patches shall be completed prior to resurfacing. Partial-depth repairs may by done prior to or in conjunction with the resurfacing operation. When partial-depth repairs are done in conjunction with the resurfacing operation, additional internal vibration will be required.

Full-depth patches in continuously reinforced concrete pavement shall be installed in accordance with the following:

The patch area shall be prepared as follows:

1. Removal. The edges of the area designated by the engineer for patching shall be sawn to a depth of 1½ inches using diamond or carborundum blades, except where a joint forms the edge. Inside the patch area, parallel to and not closer than 9 inches to the first saw cut, the concrete shall be sawn at least half the nominal pavement thickness plus 1/2 inch, or two 1½-inch saw cuts shall be made so the upper concrete can be removed and the reinforcing steel cut,

leaving the longitudinal reinforcement protruding 9 inches into the patched area. Reasonable care shall be taken to preserve transverse steel at the centerline joint of one-lane patches. Hand tools, a concrete cutter, or a tractor-boom-mounted jack hammer shall be used to cut or break along the breakout line marked around the section to be replaced, and to break out small patch areas. Large areas may be broken by used of a heavy ball, drop hammer, or other heavy equipment; however, a 2-foot strip along the breakout line shall first be broken with hand tools, a concrete cutter, or a tractor-boom-mounted jack hammer, except at the centerline joint. Heavy equipment shall not be used adjacent to concrete that has been in place less than 48 hours. The faces of pavement around a patch area shall be trimmed to reasonably neat, veritcal planes, and the cut reinforcement and attached concrete shall be removed first, and the remainder of the concrete shall then be removed in a manner such that longitudinal reinforcement is not damaged within 9 inches from the edge of the patch. A reasonable effort shall be made to leave centerline tie bars in place. Reinforcement shall not be bent more than the minimum necessary for concrete removal.

When concrete anchor lugs are encountered within an area to be patched, the anchor lugs shall be broken down to approximately 6 inches below bottom of the pavement, any exposed anchor lug reinforcing shall be removed, and the concrete shall be replaced with compacted sand or other suitable fill material to the level of the bottom of the patch.

All material removed from the pavement and not designated for salvage shall be disposed of in accordance with 1104.08.

2. Restoring the Subbase. The exposed subbase shall be cleaned of rubble and restored to its original condition by smoothing and, if necessary, hand tamping. Asphalt or cement stabilized subbase that required additional material may be patched with a suitable bituminous-aggregate mixture. Waterproof paper or plastic shall be placed over granular subgrade or subbase prior to placing the concrete.

3. Restoring the Reinforcement. The reinforcement shall be restored as follows:

The protruding and longitudinal reinforcement ends shall be made as true as practical. Bars closer to the surface than 2 inches shall be cut off flush with the edge of the patch area. Each bar shall be cleaned of loose concrete and concrete adhering beyond the deformation on the bars. Longitudinal bars shall be covered with a suitable cap, to prevent bond, prior to concrete placement.

Centerline tie bars for full-width patches shall be replaced by means of a bent bar, later straightened, and a centerline keyway may be used. Centerline tie bars damaged during removal of short, one-lane patches need not be replaced; however, replacement will be required, if necessary, so that the centerline will have two tie bars per 10 feet for patches longer than 10 feet.

Patches over 25 feet in length shall have at least one D-3 joint. Additional joints will be required for longer patches so that joints are spaced at no more than 20-foot intervals. When the area to be patched is in more than one traffic lane, the D-3 joints shall be extended through the

remaining patch areas when the adjacent patches are placed. the D-3 joint shall be as shown on Standard Road Plan RH-2, and in addition, Special Notes 1 and 2 shall apply. With approval of the engineer, the CD joint may be substituted for the D-3 joint.

Materials removed in the scarifying or repair operation shall be disposed of as shown on the plans.

Prior to applying grout in preparation for placement of new concrete, the entire surface shall be cleaned with an air blast.

It is not intended or desired that the existing concrete, prepared for resurfacing, be presaturated before grout and new concrete are placed. The prepared surface shall be dry to allow some absorption of the grout.

259.05 PLACING AND FINISHING CONCRETE. The contractor shall take every reasonable precaution to secure a smooth-riding surface. Prior to placement operations, he shall review his equipment, procedures, personnel, and previous results with the engineer, and the inspection procedures will be reviewed to assure coordination. Precaution shall include the following:

Assurance that concrete can be produced and placed within the specified limits, continuously and with uniformity.

After finishing, the contractor shall check the surface with a 10-foot, light straightedge; causes for irregularities exceeding 1/8 inch should be eliminated, and corrections should be made, if practical.

The thickness of all new concrete above the prepared surface shall be as specified on the plans.

Transverse and longitudinal joints of previously placed surface course shall be sawn to straight and vertical edges before surface course is placed adjacent to such joints.

After the surface has been cleaned and immediately before placing concrete, a thin coating of bonding grout shall be scrubbed into the dry, prepared surface. Care shall be exercised to insure that all parts receive a thorough, even coating and that no excess grout is permitted to collect in pockets. The rate of progress in applying grout shall be limited so that the grout does not become dry before it is covered with new concrete.

During delays in the surfacing operations, should the surface of the grout indicate an extensive amount of drying, additional grout shall be brushed on the area as directed by the engineer. In areas where the grout becomes thoroughly dried, the grout shall be removed by sandblasting, or other methods as approved by the engineer.

When a tight, uniform surface has been achieved, the surface shall be textured and transversely grooved in accordance with 2301.19.

After the surface has been grooved, the surface shall be cured in accordance with 2301.22A, except that liquid curing compound shall be applied at one and one-half times the specified rate.

Joints shall be sawn in the resurfacing directly over (1) the existing transverse joints, (2) both sides of each full-depth patch in continuously reinforced pavement, and (3) one side of each full-depth patch in conventionally reinforced pavement. All joints sawn in the resurfacing shall be to a width of 1/4 inch. No additional depth of sawing will be required over joints designated for partial-depth repairs. All sawn joints shall be filled in accordance with 2301.30.

Pressure-relief joints will be constructed full depth through the resurfacing and the underlying pavement as shown on the plans or as directed by the engineer. The pressure-relief joints shall be sawn in the existing pavement prior to resurfacing. The pressure-relief joints in the resurfacing shall be formed or sawn with a diamond or carborundum blade saw, over the previously sawn joint. The joint material shall be installed to complete the CF joint.

259.06 CONSTRUCTION OF TYPE B ASPHALT CEMENT CONCRETE SURFACE COURSE (SHOULDERS). DELETE the density requirements of 2303.10 for compaction of mixture placed on shoulders and add the following in lieu thereof:

After each layer has been spread, it shall be promptly and thoroughly compacted with initial, intermediate, and final rollers. Compactive effort applied to shoulder surfaces shall be substantially equivalent to that normally applied to traffic lanes; the engineer may adjust the compactive effort to prevent damage of the shoulder areas.

259.07 LIMITATIONS OF OPERATIONS. If traffic is to be maintained during the construction period of this contract, it will be noted on the plans. The contractor shall provide such traffic controls as required by the plans and specifications.

No traffic shall be permitted on Class M concrete until 72 hours after placement. No traffic shall be permitted on the resurfacing, or pavement repairs using Class C concrete, for seven (7) days after placement. At temperatures below 55 degrees F., the engineer may require a longer waiting time. No resurfacing concrete shall be placed when the air or pavement temperature is below 40 degrees F.

The contractor will be permitted to use the shoulders for construction activities, including hauling materials and mixtures on the outside shoulder. It will be the contractor's responsibility to patch, repair, or reconstruct the shoulder at his expense, as deemed necessary by the engineer, to restore the shoulders to an acceptable condition, and the contractor may elect to limit the use and vehicle loadings to minimize this work and its cost.

Delete plan notes on pages 3 and 4B pertaining to constructing subdrains prior to placing bonded PCC overlay and substitute the following in lieu thereof:

Subdrains shall be constructed before ACC shoulder surfacing is placed. If shoulders are to be used for hauling, subdrains shall be constructed after the PCC overlay is placed.

The contractor will be permitted temporary access to the project through the south right-of-way line, from private property, during the time traffic is diverted from the south roadway. If used, the contractor will be responsible for obtaining rights for use of private property, construction of the access route, and restoring the right-of-way before traffic is again routed over the south roadway and for restoring the private property in accordance with 1104.08.

259.08 METHOD OF MEASUREMENT. The quantity of the various items of work involved in the construction of portland cement concrete resurfacing will be measured by the engineer in accordance with the following provisions:

A. Portland Cement Concrete Resurfacing, Furnish Only. The amount of resurfacing concrete of the mix proportions and admixture

specified will be measured in cubic yards, using a count of batches incorporated.

B. Portland Cement Concrete Resurfacing, Placement Only. The area of portland cement concrete resurfacing, placement only, will be computed in square yards from surface measure longitudinally and the nominal plan width.

C. Surface Preparation. The amount of pavement prepared in accordance with the specifications will be measured in square yards from surface measure for each type of preparation specified. When a special preparation is required, it will be measured as shown on the plans.

D. Partial-Depth Repair. The areas of partial-depth repair of transverse joints will be computed in square yards from measurements of the report locations.

E. Full-Depth Patches. Patches involving full-depth removal of old pavement and its replacement with portland cement concrete will be computed in square yards from measurements of the areas of concrete removed, except that each patch which is less than 18 square feet in area will be counted as 2.0 square yards.

259.09 BASIS OF PAYMENT. For the performance of acceptable work, measured as provided above, the contractor will be paid the contract unit price in accordance with the following provisions.

A. Portland Cement Concrete, Furnish Only. For the number of cubic yards of portland cement concrete incorporated, payment will be made at the contract price per cubic yard, including both the Class M and the Class C concrete. This shall be full compensation for furnishing all raw materials, and for proportioning, mixing, and delivery of concrete to the paving machine, including quantities to be used for full-depth patches and partial-depth repair.

B. Portland Cement Concrete Resurfacing, Placement Only. For the number of square yards of portland cement concrete resurfacing, placement only, constructed, the contractor will be paid the contract unit price per square yard. This shall be full compensation for furnishing all labor and equipment necessary to place, finish, texture and groove, and cure the concrete, including the placement of the grout and sawing and sealing the joints, in accordance with the plans ard specifications.

C. Surface Preparation. For the square yards of pavement prepared by each method specified - 1/4-inch scarification, 1-inch scarification, each followed by sand blasting - the contractor will be paid the contract price per square yard. This shall be full compensation for preparation of the existing pavement, stockpiling material, sand blasting, and for removal and disposal of the old pavement surface material.

Special surface preparation will be paid for as shown on the plans.

D. Partial-Depth Repair. Partial-depth repair will be paid for at the contract price per square yard. This price shall be full compensation for the removal and disposal of the old pavement.

E. Full-Depth Patches. For the number of square yards of full-depth patches placed, the contractor will be paid the contract price per square yard. This price shall be full compensation for removal and disposal of the old pavement.

The intended finished shoulder and the calculated quantity of asphalt cement concrete will be based on a 5 percent slope for the first 6 feet on the inside shoulder and the first 10 feet on the outside shoulder and a 4 to 1 slope for the remaining 2 feet for both shoulders. This calculation will also modify the quantity to be paid for under Item 17, Asphalt Cement.

Article 1109.03 shall not apply to partial-depth repair, full-depth repair, or surface preparation.

The contract quantity of ACC for shoulders for this project is based on a designed, neat section 3 inches in thickness at each pavement edge and 2 inches in thickness 6 feet from the inside pavement edge and 10 feet from the outside pavement edge, plus an additional 2 feet on each shoulder with a thickness of 2 inches, as shown on the plans (28 tons per station); to this, an additional 25 percent has been added to correct existing deficiencies in elevations and slopes. It includes no quantity for patching or other repair of the existing shoulder surface. This contract quantity will be adjusted according to actual measurements that are to be taken after this section of road is closed to public traffic. Cross sections will be taken at 100-foot intervals; from these, the engineer will compute the quantity of ACC necessary to construct the overlay on the existing shoulder to the desired elevations and slopes, using a conversion factor of 2.0 tons of mixture per cubic yard. Payment for the ACC for the shoulders on both sides of the traveled way will be based on the quantity thus computed. No additional payment will be made for repair or other work, the need for which may presently exist to make the shoulder suitable for hauling or other construction activities, or for the patching, repairing, and reconstruction required by 259.07 of this specification.

Sioux City Bonded Overlay - 1978

A three-inch bonded concrete overlay was placed on a one-half-mile section of westbound Iowa 12 (then US 20) in the spring of 1978. The four-lane divided highway carried an ADT of 21,100 vehicles with 8 percent trucks down a steep grade (westbound lanes) with several signal lights. The existing pavement consisted of an old 9-inch slab that had been widened and overlayed with 3 inches of asphalt concrete during the early 1970's. The asphalt overlay on the westbound downhill lanes had corrugated from the heavy truck traffic braking for the traffic signals. This distress existed for several years and several attempts at heater planing failed to prevent reoccurrence of this distress. Therefore, a bonded concrete overlay was designed to rehabilitate the downhill westbound lanes.

The 3-inch asphalt overlay was removed with a CMI Roto-Mill Planer in one pass, and the surface of the concrete slab was milled approximately 1/4 inch in another pass. A Galion Road Planer was used to mill off local areas of asphalt that remained on the surface after the second pass. The surface was then sandblasted. The grout of 1 to 1 sand-cement mix was placed on a dry surface similar to other Iowa projects discussed in the report. A conventional concrete paving mixture was then placed using conventional paving equipment. Attempts were made to follow the existing joint pattern of the original slab and widening, but this was difficult because the existing joints were sometimes nonaligned. An average bond strength of 577 psi was measured on 5 cores cut from the pavement after construction.

The overlay was visited by the authors in August 1979 accompanied by the resident construction engineer. In general, the bonded overlay was performing very well, although some joints were showing spalling and two

or three distressed areas existed near drainage structures (cause unknown). Figures B-15 through B-22 illustrate the general condition at that time.

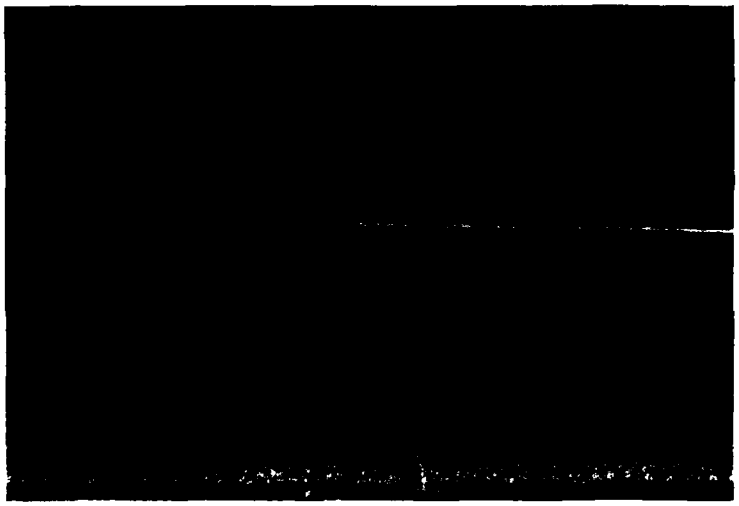


Figure B-15. Present Eastbound Asphalt Concrete Overlay. No Corrugation Exists in the Uphill Lanes.

Figure B-16. Overview of Westbound Lanes of Bonded Concrete Overlay With Longitudinal Joint Between Old Existing Outer Slab and Widening Slab--Note Spalling of Reflected Non-Sawed Longitudinal Joint.

Figure B-17. Longitudinal Joint Between Old Slab and Widening Section.

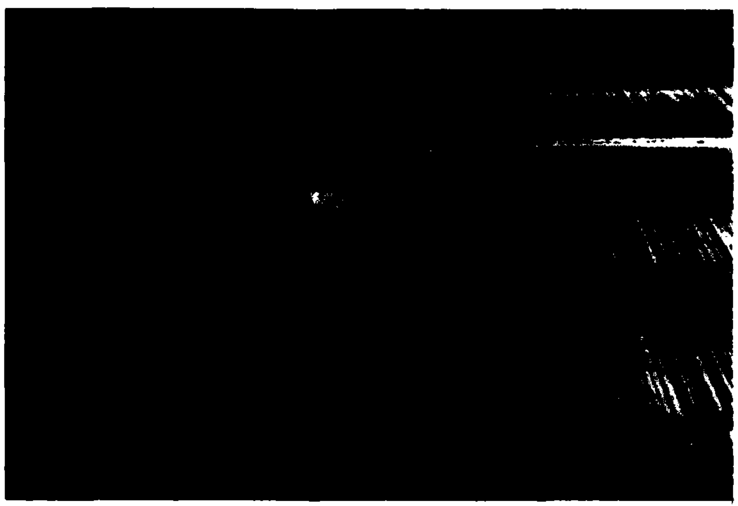


Figure B-18. Sawed and Sealed Transverse Joints (at a Section Where Existing Slab Joints Were Not Aligned).

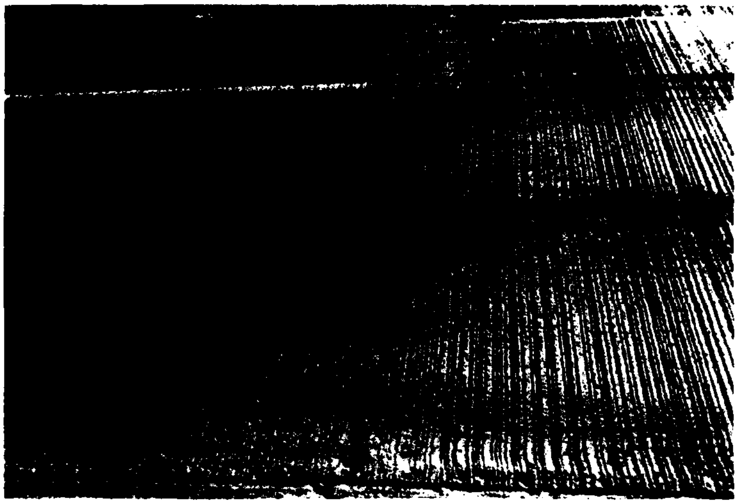


Figure B-19. Sawed Transverse Joint with Secondary Joint Cracks (This Was a Rare Occurrence).

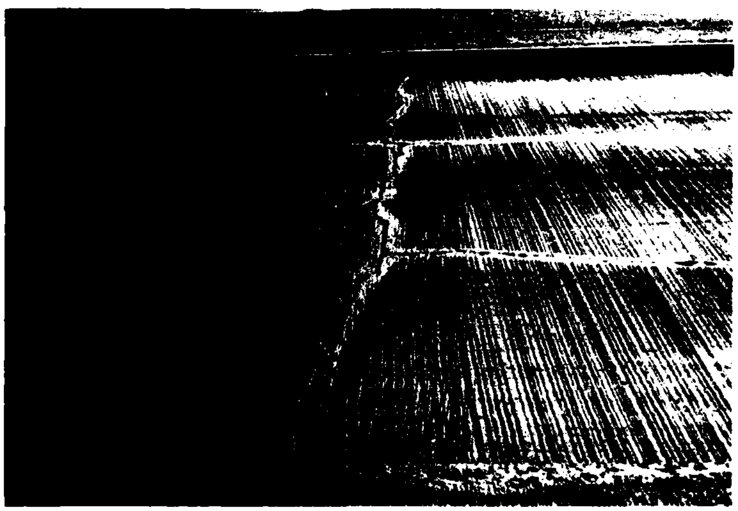


Figure B-20. Transverse and Longitudinal Crack Probably over Existing Joints Or Cracks.

Figure B-21. Partially Sawed and Non-Sawed (Cracked) Transverse Joint.

Figure B-22. Edge Failure of Overlay near Drainage Structure (Only 2-3 Occurred Along Project).

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Darter, Michael I
  Bonded concrete overlays: construction and performance / by Michael I. Darter, Ernest J. Barenberg, Darter and Barenberg, Consulting Engineers, Urbana, Ill. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1980.
  96, 3, 27 p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; GL-80-11)
  Prepared for Office, Chief of Engineers, U. S. Army, Washington, D. C., under (Project No. 4K07812AQ61) Purchase Order DACA39-79-M-0124.
  Bibliography: p. 93-96.
1. Concretes. 2. Curing. 3. Grouts. 4. Joints (Junctions). 5. Overlays (Pavements). 6. Pavements. 7. Performance. 8. Reflective cracking. 9. Reinforced concrete. I. Barenberg, Ernest J., joint author. II. Darter and Barenberg, Consulting Engineers. III. United States. Army. Corps of Engineers. IV. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; GL-80-11.
TA7.W34m no.GL-80-11